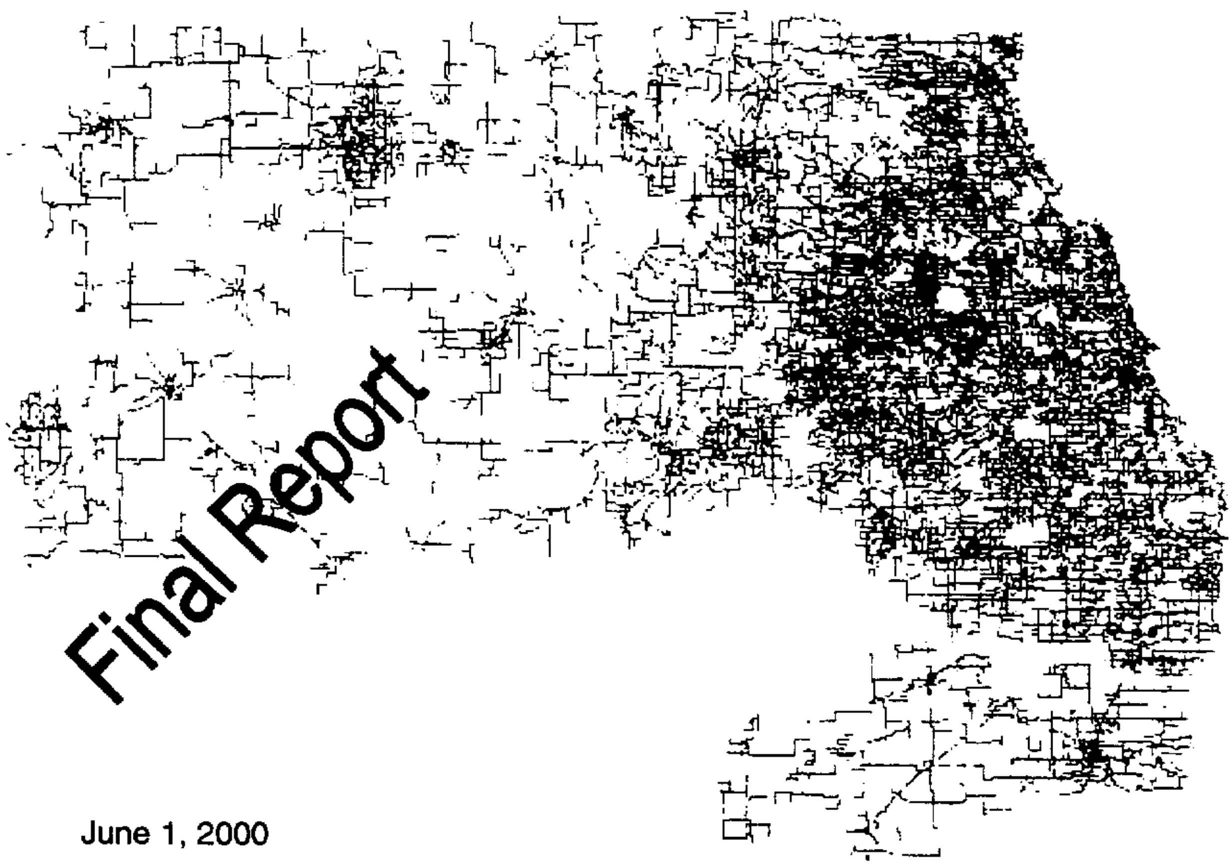
ATTACHMENT C

ComEd

ComEd Feeder System Evaluation & Performance Optimization



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Summary

This study is part of ABB's overall effort to improve the planning and operation of Commonwealth Edison's power distribution system in Chicago and the surrounding area. In this study, three main tasks were accomplished: (1) a major effort was made to create a distribution system reliability model of approximately 4000 of Commonwealth Edison's 12-kV class feeders; (2) the model was calibrated with ComEd historical data, the system reliability was assessed, and the root causes of poor reliability were identified; (3) recommendations were made to improve system reliability, the impact of the improvement projects was quantified, and the projects were ranked based on their associated cost and benefits.

From the results of the analysis, the most significant observation is that systematic overloading of the feeder system has constrained feeder transfer capacity to the point where reliability is seriously compromised. From a reliability perspective, loading equipment close to the thermal limit results in circuits that are less able to pickup load from adjacent feeders and restore interrupted customers after a fault. More customers will remain interrupted for longer periods of time and SAIDI will increase. This problem is highlighted by the fact that about 70% of all the reliability improvement projects, and 77% of the top 250 projects involve recommendations to increase feeder transfer capacity.

Insufficient feeder transfer capability is a problem that requires a long-term commitment to solve. Systematically increasing feeder transfer capacity on a large utility system can take five years or more to accomplish, even on an aggressive schedule. To improve the inherent reliability of its distribution system, Commonwealth Edison should commit to increase the transfer capacity of its distribution feeder system to a minimum of 25% from existing planning guideline of 10%. This will improve reliability, increase operational flexibility, increase equipment life and reduce the failure rates of equipment with thermally degradable insulation.

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EXECUTIVE SUMMARY

ABB has created a distribution system reliability model of approximately 4000 of Commonwealth Edison's 12-kV class feeders. The model allows the efficient computation of customer reliability and reliability indices based on system topology and component reliability data. In the same way that a power flow model can compute voltages and currents on a system, a reliability model is able to compute component outages and customer interruptions.

Distribution system reliability models can be used to examine existing reliability, look for the root causes of reliability problems, quantify the impact of reliability improvement projects and rank these projects based on their associated cost and benefits. By using this type of analytical approach, distribution reliability can be treated with analytical rigor so that higher levels of customer reliability can be obtained for lower cost. This is a business imperative since a typical distribution system accounts for up to 40% of the cost to deliver power and 90% of customer reliability problems.

Reliability modeling has been performed using ABB's proprietary software package Performance Advantage™ (PAD). Using electronic and paper maps provided by Commonwealth Edison, ABB engineers, ABB technicians and on-site Commonwealth Edison engineers generated a PAD model for each substation serving 12-kV feeders (approximately 450 substations and 4000 feeders). The loading of each feeder was calibrated based on 1999 peak conditions and the reliability data of each substation were determined based on 1999 historical reliability indices for TSS and TDC substations, and the experience of ComEd engineers. The calibrated reliability model was used to perform the following analyses:

- peak loading assessment,
- reliability assessment,
- root cause analysis,
- examination of capacity constrained load transfers,
- identification of reliability improvement projects, and
- ranking of projects based on a benefit/cost ratio.

The peak loading assessment computes voltages, currents and equipment loading under peak conditions. Geographic displays are provided to visually identify equipment that is heavily loaded or overloaded. In addition, the amount of overloaded line and cable (in feet) is provided on a feeder basis.

The reliability assessment computes the expected outage duration and interruption frequency, and the reliability indices for each substation and feeder. Using tabular and geographic displays of the results, areas of good reliability can be easily identified, areas of poor reliability can be easily identified and the spatial relationships between these areas can be easily understood. Histograms showing the predicted distribution of SAIDI and SAIFI for the Commonwealth Edison substations are shown below.

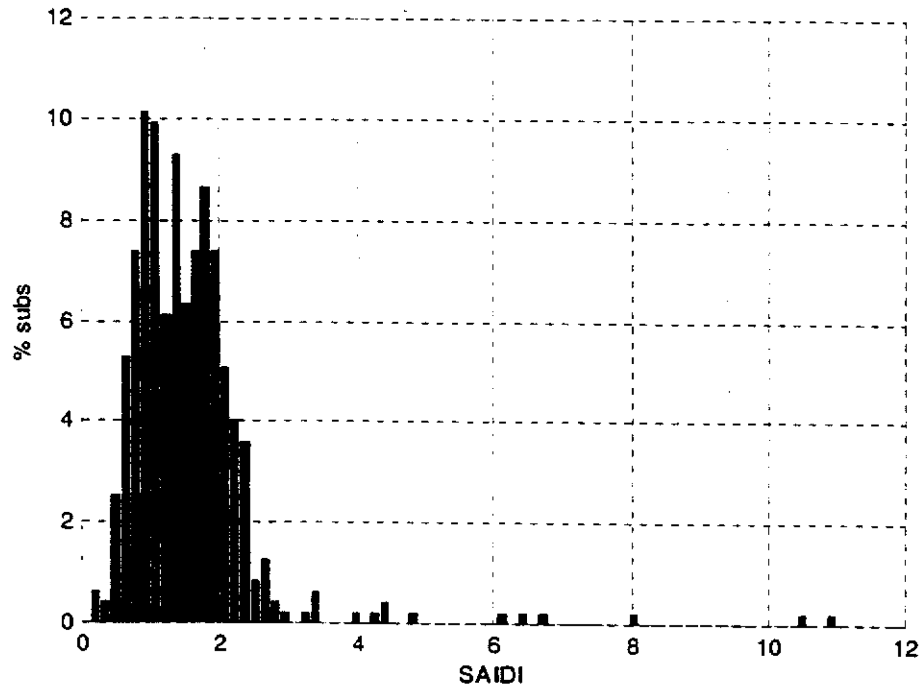

Figure 1. Histogram showing predicted SAIDI distribution for ComEd substations.

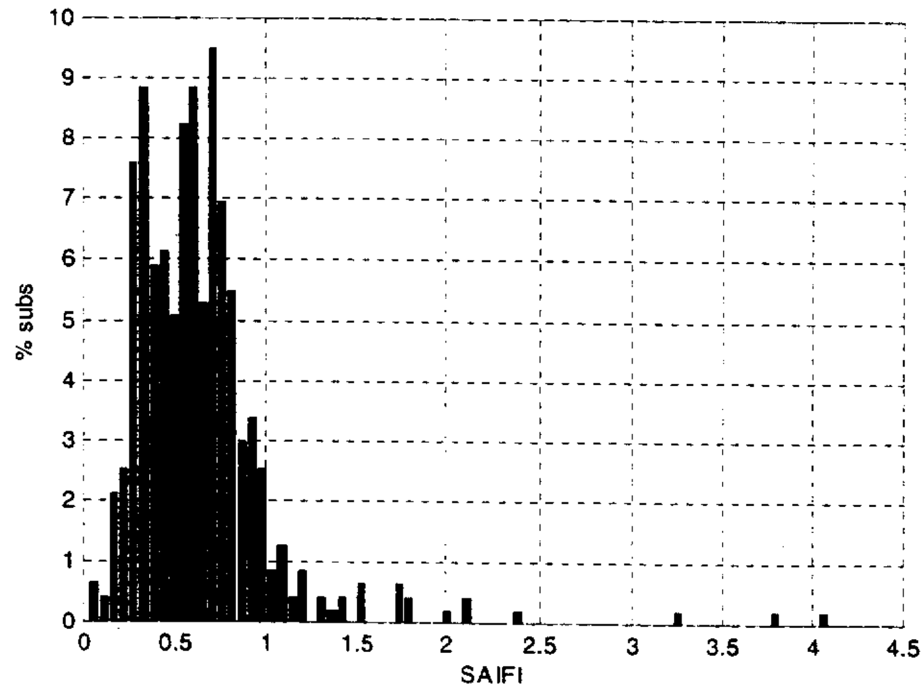

Figure 2. Histogram showing predicted SAIFI distribution for ComEd substations.

Figure 1 and Figure 2 can be interpreted as "the percentage of ComEd substations with a particular predicted SAIDI and SAIFI." For example, Figure 1 shows that about 7% of the substations have a predicted SAIDI of approximately 2.0. The SAIDI experimental distribution is centered at 1.55 with a variance of 1.03. The SAIFI experimental distribution is centered at 0.64 with a variance of 0.16. These experimental results should be interpreted carefully, especially when comparing them to the observed results. Firstly, only three years of historical data was available to calibrate the model. Secondly, data was only provided for TSS and TDC substations (mostly in the Chicago area.) which represent 41% of the substations modeled. Thirdly, the reliability results only include the effects of the three-phase portion of the system because fused lateral taps are modeled as lumped loads. In addition, predictive reliability assesses the expected state of the system and not necessarily the reliability in any one year. Considering these factors, it should not be a surprise if the observed SAIDI and SAIFI for a particular substation does not exactly match the predicted SAIDI and SAIFI. Taking a high-level view of the results, the model exposes the *long-term* implications of the system design and operation on the system reliability. It is in this light that the results and recommendations should be considered.

When one is attempting to improve system reliability, it is extremely useful to know the greatest contributing factors to poor reliability. Reliability models can generate this information using predictive root cause analysis techniques. The root cause analysis assesses the contribution of each component to poor reliability. When this information is known reliability improvement efforts can then be targeted to equipment and regions that contribute most to poor reliability.

After a fault occurs, operators will attempt to reconfigure the distribution system and restore power to as many customers as possible. Reconfiguration is only allowed if it does not load equipment above emergency ratings. Equipment that constrain post-fault reconfiguration efforts are automatically identified by the reliability model. If a component prevents a load transfer due to insufficient capacity, the probability and reliability impact of the constraints are recorded and used when generating recommendations.

In addition to examining basic loading and reliability characteristics, the reliability model looks for cost effective ways to improve reliability. Specific recommendations are based upon an approximate benefit/cost ratio referred to as the "score" of the recommendation. The score of a recommendation is defined as:

$$\text{Score} = \frac{\text{Benefit}}{\text{Cost}} \approx \frac{\text{Reduction in Interrupted kVA Hours}}{\text{Capital Cost of the Recommendation}} \quad \text{kVA - hr/\$1000}$$

Several different classes of reliability improvement options are explored. This allows different approaches to reliability improvement to be compared and ranked. Basic categories of reliability improvement projects include transfer path upgrades, new tie points, increased line sectionalizing and feeder automation. Transfer path upgrades and new tie points allow load to be more effectively transferred to adjacent feeders while a fault is being repaired. Increased line sectionalizing and automation will reduce the number of customers impacted by faults and will allow customers to be more quickly and effectively restored after experiencing an interruption. This study identifies and ranks many thousands of reliability improvement projects. Figure 3 below shows the breakdown of the top 10% most cost-effective options.

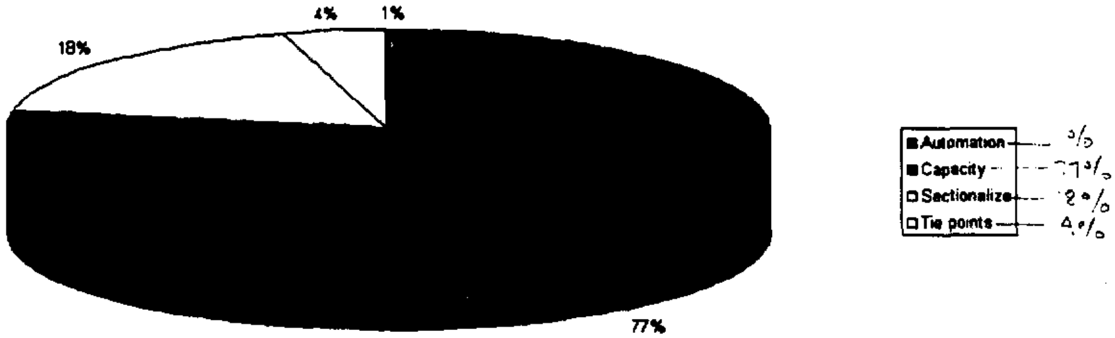

Figure 3. Breakdown of top 10% most cost-effective improvement projects.

Of the top 10% of the 2530 reliability improvement projects, 77% are recommendations for transfer path (capacity) upgrades. Based on the results of the reliability model, it is evident that the distribution system is heavily loaded to the point of reliability degradation. This is a result of capacity-focused efforts to increase asset utilization and reduce cost.

The graph below shows how reliability varies with loading on several connected distribution feeders. Reliability/loading curves tend to be "s" shaped. At low loading levels, nearly all load transfers are possible and reliability is insensitive to small variations in loading. At heavy loading levels, a high percentage of load transfers are not possible and reliability becomes very sensitive to variations in load. At dangerously high loading levels, no load transfers are possible since a majority of equipment are already loaded above emergency ratings.

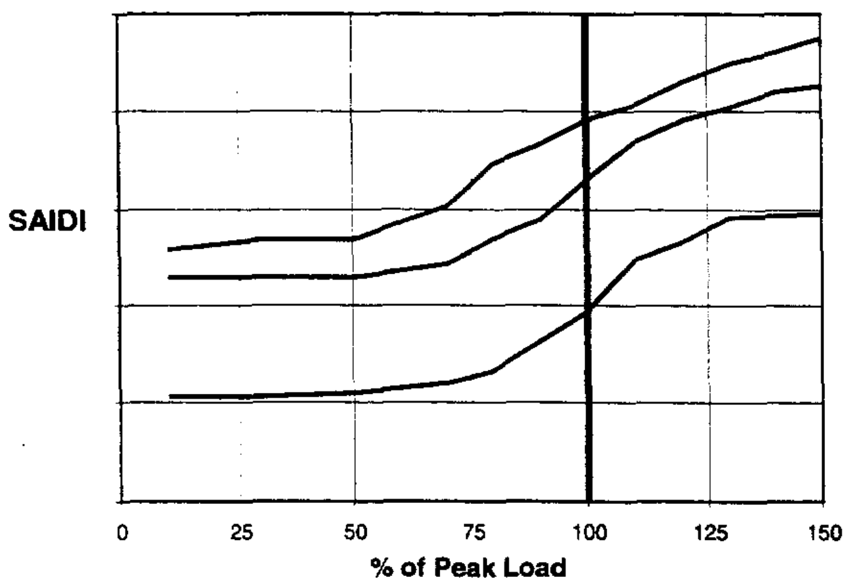

Figure 4. Variation of reliability with loading

From a reliability perspective, loading equipment close to thermal limits results in the following:

- Thermal aging of insulation increases exponentially and the expected life of equipment is generally reduced. The increase in equipment failure rates results in increased SAIFI and SAIDI values. This study does *not* model the increase in failure rates as a result of loading, but the effect is widely observed and accepted in industry.
- Circuits are less able to transfer load to adjacent feeders to restore interrupted customers after a fault. More customers will remain interrupted for longer periods of time and SAIDI will increase. This study *does* consider post fault feeder reconfiguration and captures the reliability degradation that occurs on heavily loaded systems.

Commonwealth Edison plans its distribution feeders so that 10% of load is capable of being transferred to adjacent feeders during peak loading. For systems with high transfer capability, nearly all load transfers are possible and reliability is insensitive to small variations in loading. For systems with low transfer capability, a high percentage of load transfers are not possible and reliability becomes very sensitive to variations in load. Specifics vary, but the 10% transfer capability target results in inherently low reliability for heavily loaded areas of the Commonwealth Edison distribution system. In addition, small increases in load will continue to reduce reliability. Duration related indices such as SAIDI and CAIDI are most impacted. Short-term mitigation can be accomplished by increasing the number of sectionalizing point on feeders and by using feeder automation to allow feasible load transfers to occur more rapidly.

Insufficient feeder transfer capability is a problem that requires a long-term commitment to solve. Systematically increasing feeder transfer capacity on a large utility system can take five years or more to accomplish, even on an aggressive schedule. To improve the inherent reliability of its distribution system, Commonwealth Edison should strive to increase the transfer capacity of its distribution feeder system to a minimum of 25%. This will improve reliability, increase operational flexibility, increase equipment life and reduce the failure rates of equipment with thermally degradable insulation.

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1 Introduction

Electric utilities are under increasing pressure to reduce costs and to improve reliability. Since a typical distribution system accounts for 40% of the cost to deliver power and 80% of customer reliability problems, distribution system design and operation is critical for financial success and customer satisfaction.

To make substantial gains in cost and reliability, utilities must shift from capacity planning to reliability planning. Just as equipment loading and voltage regulation are treated with analytical rigor in capacity planning, interruptions and outages must be treated with analytical rigor in reliability planning. This is made possible through the use of predictive reliability assessment models that are able to predict customer reliability characteristics based on system topology and component reliability data. Just as a power flow model is able to predict currents and voltages, a reliability model is able to predict expected interruption frequencies and durations.

The goal of this project is to create a reliability model for approximately 4000 of Commonwealth Edison's 12-kV class distribution feeders. For each load point, the model will be able to predict the expected number of interruptions per year and the expected number of interruption hours per year. These load point results are aggregated into reliability indices (SAIFI and SAIDI) for each feeder and each substation. This distribution system reliability model will enable Commonwealth Edison will be able to treat reliability problems with analytical rigor that was not possible in the past.

1.1 Benefits of Distribution Reliability Modeling

The primary capability of a reliability model is to quantify the reliability of a system design. Areas of inherently good reliability can be identified, areas of inherently poor reliability can be identified, and the geo-spatial relationship of these areas can be examined. The model also identifies overloaded equipment and components that degrade reliability because otherwise beneficial load transfers result in overloads. Other useful results include the expected number of times that protection devices will operate and the expected number of times that switches will be used.

After examining the reliability characteristics of a system, it is useful to look at the underlying causes of poor reliability (root causes). For each reliability index, the model is able to identify components that have the most negative impact. For example, a line section with a high failure rate may have a low root cause score if it has a small number of downstream customers or if the downstream customers are able to be quickly transferred to another circuit. Conversely, a line section with a low failure rate may still have a high root cause score if it has a large number of downstream customers and if these customers cannot be transferred to alternate circuits. Used in this way, a root cause analysis gives valuable information when identifying potential reliability improvement options.

The true power of a predictive reliability assessment model is its ability to quantify the impact of design improvement options. Adding a recloser to a circuit will improve reliability–but by how much? A reliability model will quantify improvements that can be expected for each individual customer. Blocking the instantaneous trip on a main feeder breaker with reclosing will reduce momentary interruptions and increase sustained interruptions. The reliability model will help answer whether this trade-off is worthwhile by precisely quantifying various effects. A list of typical design improvement options that a predictive reliability model can be explore includes:

- Transferring load between feeders
- Adding new substations
- Adding new feeders
- Adding line reclosers
- Adding sectionalizing switches
- Adding ties to adjacent circuits
- Automating feeder switches
- Undergrounding circuits with high exposure
- Replacing old equipment

A design improvement project will result in reliability improvements to certain customers. Different project variations will impact these improvements and companion projects can be constructive or destructive. A reliability model can help examine the reliability implications of these variations and combinations. It can help to answer the questions such as the number of sectionalizing switches that should be placed on a feeder, the optimal location of devices, the optimal ratings of new equipment, and so on. In addition, some project combinations will result in reliability improvements that are greater or less than the sum of the individual projects looked at in isolation. For example, adding a recloser may result in a SAIDI reduction of 30 minutes and undergrounding a downstream cable section may result in a SAIDI reduction of 30 minutes. Since both of these projects are targeted at eliminating temporary overhead faults, executing both projects may only results in 40 minutes of SAIDI reduction. The opposite effect is also possible. Adding a tie switch may result in a SAIDI reduction of 10 minutes and reconductoring a small conductor may result in a SAIDI reduction of 5 minutes. Since reconductoring may cause the tie switch to be more effective, executing both projects may result in a SAIDI reduction of 30 minutes.

Quantifying the reliability of projects and project combinations is only half of the problem. Since a utility is concerned with both reliability and cost, projects should be chosen based on cost effectiveness. "Cost effectiveness" is quantified by calculating the cost of each reliability improvement option and computing a benefit/cost ratio. This is a measure of how much reliability is purchased with each dollar being spent. Once all projects are ranked in order of their cost effectiveness, projects and project combinations can be approved in order until reliability targets are met or budget constraints become binding.

1.2 Scope and Process

As previously mentioned, the goal of this project is to create a reliability model for approximately 4000 of the 12-kV class feeders that make up the Commonwealth Edison distribution system. This modeling, performed at ABB's Centennial Campus Site in

Raleigh, NC, was performed by a combination of ABB Engineers, ABB Technicians, and engineers from Commonwealth Edison's distribution planning group.

System models are based on three primary sources of information: data from Commonwealth Edison's DINIS database (for Chicago Area feeders), data from Commonwealth Edison's CEGIS database (for feeders outside of the Chicago Area), and distribution feeder maps. Systems were modeled on a substation basis and examined by on-site Commonwealth Edison engineers for accuracy. Substation models were then aggregated into study areas for analysis. Before performing an analysis, each study area was calibrated based on historical loading and reliability data supplied by Commonwealth Edison. This ensures that the models are consistent with the actual system.

A reliability analysis of each study area was performed and the resulting reliability indices are presented for each substation and each feeder. In addition, graphical results are provided to show the location of equipment overloads, interruption frequency, interruption duration, the root causes of interruption frequency, the root causes of interruption duration, and equipment that prevent load transfers due to capacity constraints.

The last goal of this project is to provide a list of reliability improvement recommendations. These recommendations are categorized by substation and ranked based on an approximate benefit/cost ratio. Benefit is defined as the reduction in interrupted kVA-hours, and cost is defined as the initial cost to purchase and install the equipment associated with the project (in $1000s). Equivalently, benefit/cost is the reduction in interrupted kVA-hours per thousand dollars.

1.3 Context of Recommendations

The recommendations detailed in this report are based exclusively on the reliability model. As such, they do not take into consideration external factors that may influence the attractiveness and feasibility of various design improvement options. These recommendations should be used as a starting point and guide when identifying cost effective alternatives to improve reliability to customers, feeders and substations. In addition, recommendations are ranked based on an approximate kVA-hr reduction per $1000. If other criteria are relevant in specific situations, the reliability model should be revisited and the impact of design improvement options on these new criteria should be examined.

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2 Methodology

The purpose of this study is to look at the reliability of the Commonwealth Edison distribution system with analytical rigor. The primary tool used is *a predictive reliability assessment model*. This is a model that is able to predict the reliability of customers based on system topology and component reliability parameters. For each component on the system, a predictive reliability assessment model is able to compute the following information:

- Number of Momentary Interruptions per Year
- Number of Sustained Interruptions per Year
- Number of Interrupted Minutes per year

Based on these results, good and bad areas of reliability can be identified and the impact of design improvement projects can be quantified. This allows the value of various options to be compared so that (1) reliability targets can be met for the least possible cost, (2) the best reliability can be achieved for a constrained budget, and (3) tradeoffs between reliability and budgets can be understood.

Electric utilities often use reliability indices to quantify the reliability of their system. These indices can be easily computed from the primitive values generated by a reliability assessment model. This report assumes that the reader is familiar with reliability indices such as SAIFI and SAIDI. Readers unfamiliar with these terms are referred to Appendix A.

2.1 Software

The modeling in this report is performed using ABB's proprietary reliability assessment program Performance Advantage™ (PAD). This is an ABB in-house engineering tool and is not commercially available. Performance Advantage consists of four main components: a user interface, analysis engines, system databases and component data libraries.

The Performance Advantage user interface is designed for rapid model development and rapid model modification. It is designed to be very flexible in its operation, geographic in its representation, and graphical in its treatment of data and results. A screen capture Performance Advantage showing the feeders in Downtown Chicago is shown in Figure 5 below.

The Performance Advantage user interface is linked to a several analysis engines. This allows various types of analyses to be performed on a single system model. The primary analysis engines used in this study are the power flow engine and the reliability assessment engine. The power flow engine computes currents and voltages and is able to identify overloaded equipment. The reliability engine computes outages and interruptions and is able to identify areas in need reliability improvement.

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Each system model is stored in an Access database. These models are component based (as opposed to arc-node) and connectivity is inferred by coincident component endpoint locations. Each access database is completely self-contained in that it contains all system data needed by the engines to analyze a particular model.

Each system model is linked to a component data library. This is a set of component templates with default data assigned to each template. When a new component is entered, it's data fields are automatically populated according to its default template (these can later be customized). A component data library has been specifically constructed for this project and all models are linked to this common library.

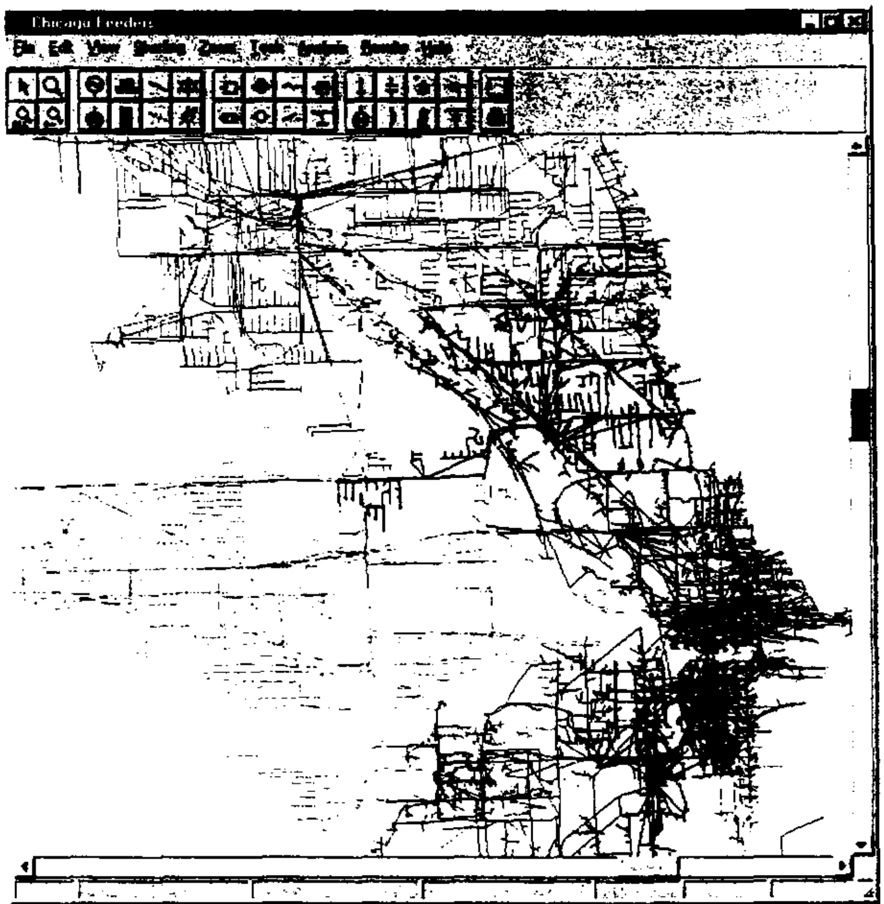

Figure 5. Performance Advantage User Interface

2.2 System Modeling

When modeling large systems, it is advantageous to transfer existing electronic system data into Performance Advantage whenever possible. This reduces manpower requirements and improves model accuracy. This project obtained electronic system data from two primary sources: Commonwealth Edison's DINIS database and Commonwealth Edison's CEGIS database. DINIS is the power flow model that

Commonwealth Edison uses. Most of the Chicago region feeders have been modeled in DINIS. CEGIS (Commonwealth Edison Geographic Information System) is a Smallworld database that Commonwealth Edison uses for asset management. Most of the non-Chicago region feeders have been modeled in CEGIS.

Commonwealth Edison supplied ABB with geographic information from its DINIS database. This data included the endpoint location and lengths for line and cable sections. A translator was created to import this information into Performance Advantage. Once imported, substations were manually entered based on one-line diagrams supplied by Commonwealth Edison. Line devices such as switches and loads were then entered based on paper maps supplied be Commonwealth Edison. Modeling the "DINIS Area" was manually intensive when compared to the "CEGIS Area."

Commonwealth Edison supplied ABB with geographic information from its CEGIS database. This data included endpoint location and lengths for line and cable sections. In addition, component information such as loads and line devices were provided. A translator was created to import this information into Performance Advantage. This translator automatically compressed single-phase fused laterals into an equivalent lumped load just downstream of the fuse. Once imported, substations were manually entered based on one-line diagrams supplied by Commonwealth Edison. Ties between feeders were identified by the translator and manually verified using paper maps.

The reliability models used in this project do not include fused lateral taps. These branches are modeled as a lumped load at the tap point. As such, the reliability results will only include the effects of the three-phase portion of the system. This is sufficient and preferable for this type of analysis, but will result in mismatches in computed reliability versus historical reliability for feeders with long lateral taps.

2.3 Verification and Calibration

The Commonwealth Edison system was imported on a substation by substation basis. After being imported, the substations were manually entered and an ABB engineer or technician compared the model to paper maps provided by Commonwealth Edison. In this way, missing data was entered and feeder inter-ties were made. Once complete, substations were given to on-site Commonwealth Edison planners to verify that the system model accurately reflected the paper maps.

After the system topology of a substation had been verified, each feeder was calibrated so that the peak load on the feeder and the number of customers on the feeder matched the quantities shown in files supplied by Commonwealth Edison. This was done by proportionally scaling transformer loads and transformer customers. If customer information was not available for a substation, an assumption of 5-kW per customer was made.

Each substation was also calibrated to some extent based on Commonwealth Edison historical reliability performance. ABB was supplied with 1999 SAIFI and SAIDI indices for TDC and TSS substations. These values and the experience of on-site ComEd engineers were used to identify reasonable values to use for cable and line reliability parameters such as failure rate and mean time to repair. After modeling, verification and calibration, the result was a good "as is" representation of Commonwealth Edison's distribution feeder system. This model was then used as a basis for identifying equipment overloads, reliability problems, reliability root causes, and potential reliability solutions.

2.4 Study Areas

After the substations were modeled and calibrated, they were assembled into study areas. A study area consists of a group of core substations. When a study area is analyzed, the surrounding feeders that interconnect with these substations are included in the model. This allows a study area to be analyzed while including the effects of load transfers to interconnected feeders not included in the study area.

2.5 Peak Loading Assessment

A peak loading assessment has been performed for all of the line sections in the feeder model. This analyses runs a power flow (assuming peak loading conditions) and determines the loading of the section based on its normal rating. A graphical representation of peak loading is provided for each study area. This geographical picture shades each component based on its % loading at peak (feeders not in the study area are shaded gray). Components that are overloaded at peak are shaded red.

In addition to the graphical representation of peak loading, a summary of overloads is provided for each feeder that has any overloaded components. This consists of the total length of overloaded circuits and the maximum overload seen.

2.6 Reliability Assessment

A reliability assessment has been performed for each analysis area. Tabular results of SAIFI and SAIDI are provided for each substation and for each feeder within the substations. In addition, two graphical representation of reliability are provided for each study area. This included a visualization of the expected number of outages that different parts of the system can expect per year and a visualization of the expected number of outage hours that different parts of the system can expect per year. The best areas of reliability are shaded in black and the worst areas of reliability are shaded in red (feeders outside of the study area are shaded in gray).

The legend for each of these displays is scaled so that a reasonable percentage of the system is shaded in red. This insures that problem areas can be readily identified. Care should be taken when comparing visualizations between different study areas since the colors will correspond to different levels of reliability.

2.7 Root Cause Analysis

When attempting to improve reliability indices, it is helpful to know the greatest contributing factors to these indices. Performance Advantage automatically does this by a process referred to as a predictive root cause analysis. This is different than a historical root cause analysis (which typically identifies the physical cause of faults) in that it computes each component's contribution to reliability indices.

To illustrate, consider a cable section with a failure rate of 0.1 /mi/yr. If this cable fails, customers in the study area are impacted in the following way:

90%	No effect
8%	1 hour interruption
2%	4 hour interruption

The SAIDI root cause score for this cable section is equal to its contribution to SAIDI. For lines and cables, this is given in per unit length values. In this case:

SAIDI Root Cause Score = (8% x 1 hour + 2% x 4 hours) x 0.1 /mi/yr.

Visualizations are provided for the root cause analysis of SAIFI (SAIFI RCA) and the root cause analysis of SAIDI (SAIDI RCA). Areas with the lowest root cause are shaded in black and areas with the highest root cause are shaded in red. The legend for each of these displays is scaled so that a reasonable percentage of the system is shaded in red. This insures that problem areas can be readily identified. Care should be taken when comparing visualizations between different study areas since the colors will correspond to different levels of root cause.

2.8 Capacity Constrained Load Transfers

After a fault occurs, the reliability model will attempt to reconfigure the system and restore loads to as many customers as possible. Reconfiguration is only allowed if it does not load a piece of equipment above its emergency rating. If a load transfer is not allowed because it will overload a component, the component is charged with a capacity constraint that includes both the frequency of the constraint and the amount of kVA that was constrained. Visualizations of these results are provided for each study area. This allows highly constrained areas of the system to be readily identified. The legend for each of these displays is scaled so that a reasonable percentage of the system is shaded in red. This insures that problem areas can be readily identified. Care should be taken when comparing visualizations between different study areas since the colors will correspond to different levels of constraint.

2.9 Identifying Recommendations

In addition to examining basic loading and reliability characteristics, each study area is examined for cost effective ways to improve reliability and general (high level) and specific (medium level) recommendations are made.

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The first category of general recommendations is based on overloaded components. If a line section of cable section is overloaded under peak loading conditions, it is a reliability concern and a general recommendation to eliminate the overload is generated.

The second category of general recommendations is based on the relative differences in reliability between feeders served by the same substation. If the SAIFI or SAIDI of a feeder is substantially worse that the SAIFI or SAIDI of the substation serving it, customers on that feeder are likely to complain. Recommendations are made to improve the reliability of such feeders.

Specific recommendations are based upon an approximate benefit/cost ratio referred to as the "score" of the recommendation. The score of a recommendation is defined as:

$$\text{Score} = \frac{\text{Benefit}}{\text{Cost}} \approx \frac{\text{Reduction in Interrupted kVA Hours}}{\text{Capital Cost of the Recommendation}} \quad \text{kVA - hr/\$1000}$$

Several different classes of reliability improvement options are explored. This allows different approaches to reliability to be compared from a value perspective. Basic categories of the options explored include:

2.9.1 Transfer Path Upgrades

A transfer path is an alternate path to serve load after a fault occurs. If a transfer path is capacity constrained due to small conductor sizes, reconductoring may be a cost-effective way to improve reliability. The software scores each transfer path based on the amount of constrained kVA that is relieved and the cost of reconductoring.

2.9.2 New Tie Points

A tie point is a normally open switch that allows a feeder to be connected to an adjacent feeder. Adding new tie points increases the number of possible transfer paths and may be a cost-effective way to improve reliability on feeders with low transfer capability. The software scores each possible new tie point location based on the reliability, loading and topology of the connected feeders and on the distance between the feeder connection points.

2.9.3 Increased Line Sectionalizing

Increased line sectionalizing is accomplished by placing normally-closed switching devices on a feeder. These devices can either have fault interrupting capability (reclosers) or no fault interrupting capability (switches). The software scores each possible sectionalizing location based on the ability for the device to restore power to customers that would not otherwise be restored under certain fault conditions.

3 Summary of Results and Recommendations

This section aggregates specific findings from the study analyses and provides some synthetic results so that larger reliability trends and features can be identified and understood. The summary begins with an overall assessment of the state of the distribution system. Section 3.1 summarizes substation reliability results, section 3.2 summarizes the specific recommendations for improving reliability. The summary includes tables and graphics highlighting each of the four regions of ComEd's distribution system.

3.1 Overall Assessment

A significant portion of the Commonwealth Edison distribution system is heavily loaded to the point of reliability degradation. This is a result of capacity-focused efforts to increase asset utilization and reduce cost. From a reliability perspective, loading equipment close to thermal limits results in the following:

- Thermal aging of insulation increases exponentially and the expected life of equipment is generally reduced. The increase in equipment failure rates results in increased SAIFI and SAIDI values. This study does *not* model the increase in failure rates as a result of loading, but the effect is widely observed and accepted in industry.

- Circuits are less able to transfer load to adjacent feeders to restore interrupted customers after a fault. More customers will remain interrupted for longer periods of time and SAIDI will increase. This study *does* consider post fault feeder reconfiguration and captures the reliability degradation that occurs on heavily loaded systems.

The *transfer capability* of a feeder is the percentage of load that can be transferred to other feeders at peak load. A feeder that can transfer 30% of load at peak has a transfer capability of 30%. Best practice distribution system designs have a transfer capability between 25% and 35%, and lower percentages directly result in reduced system reliability.

Commonwealth Edison plans its distribution system to have a transfer capability of 10%. This is only a target and feeders are not required to meet it. A heavily loaded Commonwealth Edison substation in the Northwest region, Arlington, demonstrates the impact of insufficient transfer capability on distribution system reliability. At 1999 peak load, Arlington has a SAIDI 2.94 hr/yr. This value is very sensitive to variations in loading level. If feeder loading on Arlington and its interconnected feeders were 25% of present values, SAIDI will be reduced by 13%. If loading levels are increased by 10%, SAIDI will increase by 7%. Variations in SAIDI with loading for Wheeling,and Aptakasic substations are shown below:

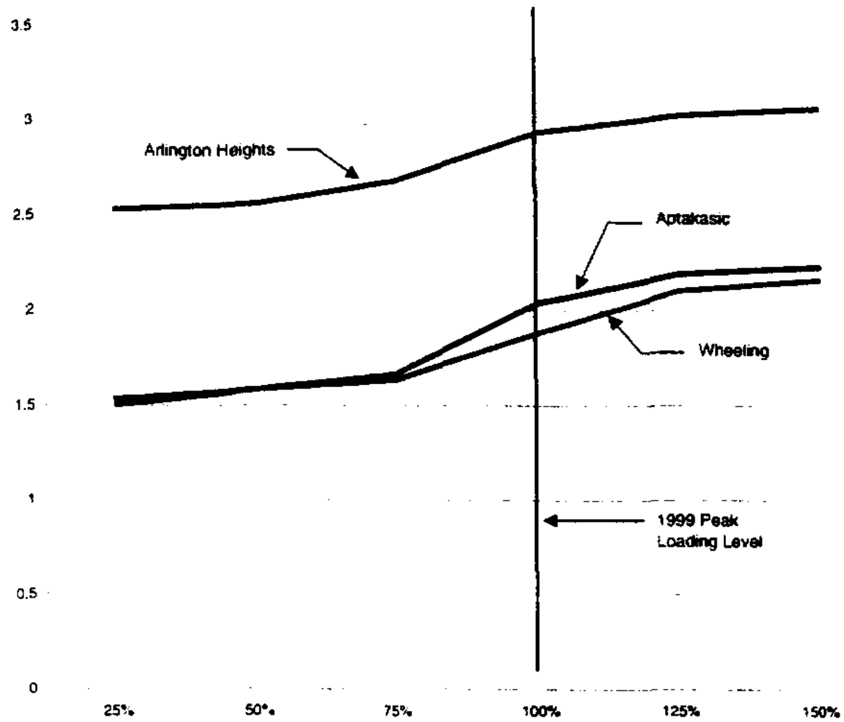

Figure 6. Impact of Heavy Feeder Loading on Distribution Reliability

Reliability/loading curves, as seen in Figure 6, tend to be "s" shaped. At low loading levels, nearly all load transfers are possible and reliability is insensitive to small variations in loading. At heavy loading levels, a high percentage of load transfers are not possible and reliability becomes very sensitive to variations in load. At dangerously high loading levels, no load transfers are possible since a majority of equipment are already loaded above emergency ratings.

From a reliability perspective, Arlington, Wheeling and Aptakasic are all loaded about 25% higher than desirable levels. At 75% loading, the reliability of these stations starts significantly degrading as load increases. Specifics vary, but the 10% transfer capability target puts heavily loaded areas of the Commonwealth Edison distribution system in similar situations. Several comments to note include:

- This is a problem that requires a long-term commitment to solve. Systematically increasing feeder transfer capacity on a large utility system can take five years or more to accomplish.

- Duration related indices such as SAIDI and CAIDI are most impacted. From a systems perspective, short-term mitigation can be accomplished by increasing the number of sectionalizing point on feeders and by using feeder automation to allow feasible load transfers to occur more rapidly.

To improve the inherent reliability of its distribution system, Commonwealth Edison should strive to increase the transfer capacity of its distribution feeder to a minimum of

25%. This will improve reliability, increase operational flexibility, increase equipment life and reduce the failure rates of equipment with thermally degradable insulation.

3.2 Substation Reliability

This section presents a detailed reliability analysis for each substation. Results are grouped by ComEd regions so that specific geographic areas can be more easily examined. Table 1 below is a summary of the overall substation reliability results. This table can be used to compare all the substations each other.

Table 1. Summary of Substation Reliability Results

Substation	Peak Load (kVA)	% Underg.	SAIFI calc.	SAIDI calc.	#feeders	# over-loaded feeders
DCA12	8515	31	0.67	1.34	1	1
DCA15	7216	33	0.6	1.24	1	0
DCA24	10016	8	0.43	0.98	2	0
DCA27	5196	12	1.29	2.27	1	0
DCA31	11921	12	0.67	1.34	3	0
DCA41	7577	37	0.46	0.94	1	0
DCA47	19112	32	0.8	1.91	2	0
DCA50	3536	23	0.22	0.55	1	0
DCA57	6495	7	0.44	0.96	1	0
DCA67	18179	47	0.46	1.16	3	1
DCA68	14361	9	0.32	0.96	2	0
DCA70	17175	29	0.47	1.16	3	0
DCA71	14000	17	0.38	0.83	3	1
DCA81	5917	30	0.95	1.88	1	1
DCA82	12557	22	0.66	1.43	3	0
DCA87	13928	29	0.68	1.48	2	1
DCA91	11763	13	0.57	1.37	2	0
DCA94	11258	46	0.6	1.68	2	1
DCB10	10283	9	0.68	1.6	2	0
DCB11	10586	17	0.53	1.65	2	0
DCB12	2100	2	0.5	1.63	1	1
DCB15	5758	5	0.38	1.12	2	0
DCB16	13307	12	0.78	2.15	2	1
DCB17	5629	7	0.42	1.13	1	1
DCB20	12492	10	0.5	1.43	2	1
DCB26	4070	2	0.59	1.91	1	0
DCB27	4474	3	0.26	0.72	1	0
DCB28	3357	1	0.32	1.05	2	0
DCB29	13487	11	0.22	0.55	2	1
DCB30	8912	2	0.34	0.85	3	0
DCB31	9699	12	0.55	1.45	2	1
DCB32	2446	2	0.58	1.89	1	0
DCB35	952	1	1.73	4.43	1	0
DCB36	7433	3	0.56	1.69	2	0
DCB37	4366	4	0.81	2.44	1	0
DCB39	3039	0	0.4	1.24	2	1
DCB42	3687	3	2.39	6.36	2	0

Substation	Peak Load (kVA)	% Underg.	SAIFI calc.	SAIDI calc.	#feeders	# over-loaded feeders
DCB43	6119	3	2.03	6.08	1	0
DCB44	6170	0	4.09	11	2	1
DCB45	4936	1	3.8	10.5	2	0
DCB46	4257	1	1.72	4.39	1	1
DCB47	5564	1	0.74	1.97	3	0
DCB48	4979	3	3.27	8.07	1	1
DCB50	3896	25	2.13	6.73	1	0
DCB51	11315	8	0.39	0.94	3	1
DCB52	3889	1	0.38	1.04	2	0
DCB53	10081	13	0.45	1.31	3	0
DCB54	5369	5	0.67	1.93	1	0
DCB55	8198	2	0.91	2.18	2	0
DCB57	6928	6	0.77	1.9	1	0
DCB63	3103	1	1.79	4.22	1	0
DCB64	4106	3	0.45	1.37	2	0
DCB86	2286	0	0.7	2.19	1	0
DCB89	2636	4	1.78	4.84	1	0
DCB90	6980	7	1.38	3.45	2	0
DCB95	3734	16	0.6	1.29	1	0
DCC20	11113	63	0.4	0.88	2	0
DCC23	5123	27	0.18	0.51	2	0
DCC3	6711	20	0.34	0.96	1	0
DCC30	14373	72	0.72	1.78	2	1
DCC33	4000	13	0.19	0.54	1	0
DCC34	6422	46	0.78	1.6	1	0
DCC53	5116	35	0.69	1.19	1	0
DCC57	6639	33	0.73	1.4	1	0
DCC60	0	3	0.39	0.78	1	0
DCC61	7938	62	0.59	1.09	1	1
DCC66	3207	44	0.31	0.7	1	0
DCC73	6350	32	0.44	1.14	1	0
DCC80	4208	7	0.35	0.71	1	0
DCC85	5932	51	0.29	0.92	1	1
DCC91	2038	27	0.29	0.65	1	0
DCC97	3788	1	0.33	0.68	1	0
DCD114	7433	7	0.59	1.07	1	1
DCD13	6018	4	0.32	0.64	2	0
DCD133	6213	13	0.48	0.88	1	0
DCD16	2791	45	0.35	0.96	1	1
DCD17	5131	40	0.3	0.71	1	0
DCD175	8443	3	0.45	1.08	1	1
DCD187	7642	30	0.56	1.11	2	0
DCD20	4481	0	0.26	0.62	1	1
DCD229	7938	16	0.53	1.31	1	1
DCD242	5701	28	0.41	1.03	1	0
DCD244	5917	8	0.4	0.94	1	1
DCD255	5629	3	0.55	1.11	1	0

Substation	Peak Load (kVA)	% Underg.	SAIFI calc.	SAIDI calc.	#feeders	# over-loaded feeders
DCD351	12124	32	0.61	1.4	2	1
DCD40	12917	13	0.66	1.73	2	1
DCD46	12210	12	0.56	1.18	1	2
DCD47	5693	6	0.42	1.3	1	0
DCD62	12405	10	0.75	1.39	1	1
DCD63	10175	19	0.47	1.09	3	1
DCD67	7945	3	0.4	0.85	3	0
DCD69	5347	14	0.28	0.62	1	0
DCD80	7577	12	0.5	1.19	1	0
DCD87	6343	22	0.39	0.87	1	0
DCD99	4113	1	0.4	0.71	1	1
DCE08	5951	30	0.33	0.64	2	0
DCE10	8912	60	0.36	0.84	2	0
DCE11	24248	10	0.58	1.31	3	0
DCE12	3788	100	0.03	0.14	1	0
DCE16	17355	10	0.78	1.72	2	2
DCE17	8696	3	1.29	2.41	1	0
DCE18	13278	62	0.44	1.03	2	0
DCE19	15876	11	0.68	1.44	2	0
DCE20	25193	16	0.78	1.65	3	1
DCE21	5809	6	0.87	1.95	1	0
DCE22	17753	38	0.4	1.09	3	1
DCE24	17464	13	0.45	0.92	3	0
DCE26	30136	49	0.97	2.29	3	2
DCE28	18048	37	0.52	1.28	3	1
DCE35	12990	15	0.88	1.72	2	0
DCE46	8443	22	0.49	1.05	1	0
DCE59	9771	26	0.78	1.33	1	0
DCE69	19153	29	0.36	1.05	3	0
DCE71	7642	28	1.22	2.3	2	0
DCE77	19261	26	0.55	1.41	2	1
DCE79	10248	8	0.53	1.09	2	0
DCE82	11113	4	1.39	2.74	2	0
DCF12	18315	5	0.76	1.71	2	1
DCF122	7036	5	0.32	0.91	1	0
DCF149	13964	5	0.69	1.79	2	1
DCF16	5910	1	0.34	0.68	1	1
DCF17	7209	3	0.96	1.34	1	0
DCF36	4546	7	1.22	1.81	1	0
DCF45	13552	8	0.75	1.2	2	1
DCF73	NA	6	0.43	0.88	1	0
DCF96	13358	3	0.38	0.96	2	1
DCG121	4005	13	0.19	0.5	1	0
DCG128	4611	23	0.13	0.4	2	0
DCG19	5268	19	0.34	0.83	1	0
DCG42	6783	23	0.61	1.31	1	0
DCG78	13062	1	0.35	1.13	2	0

Substation	Peak Load (kVA)	% Underg.	SAIFI calc.	SAIDI calc.	#feeders	# over-loaded feeders
DCG88	5989	13	0.38	0.78	1	0
DCG99	6863	11	0.59	1.25	1	0
DCH10	4820	2	0.56	1.42	2	0
DCH23	9374	3	0.45	1.02	2	0
DCH25	11438	6	0.31	0.82	3	2
DCH26	11005	2	0.71	1.83	2	0
DCH27	7433	9	1.09	2.29	1	1
DCH28	4503	5	0.74	1.99	2	1
DCH36	4733	5	0.98	2.42	2	1
DCH38	1688	3	0.81	2.52	1	0
DCH39	9598	9	0.56	1.56	2	1
DCH40	5513	4	0.52	1.46	2	1
DCH41	7793	19	0.88	2.79	1	1
DCH43	1659	2	0.39	1.18	1	0
DCH44	2504	3	0.24	0.75	2	0
DCH47	7296	2	0.78	2.26	2	1
DCH49	4257	2	0.21	0.63	2	0
DCH50	3723	2	0.75	2.13	1	1
DCH52	2727	3	0.29	0.94	1	1
DCH53	8605	1	0.84	2.4	2	0
DCH54	1298	1	0.72	1.91	1	0
DCH56	2273	0	0.46	1.34	2	0
DCH57	1347	2	0.26	0.8	2	0
DCH59	2381	11	0.51	1.59	1	0
DCH60	14072	14	0.71	1.69	2	0
DCH62	4387	1	0.4	0.93	1	0
DCH65	6383	8	0.52	1.42	1	1
DCH67	8371	2	0.64	1.82	2	0
DCH70	8183	17	0.57	1.43	2	0
DCH78	10240	15	0.72	1.77	2	0
DCH91	6061	2	0.63	1.77	1	1
DCJ13	3853	0	0.28	0.73	1	0
DCJ16	2792	0	0.35	0.77	1	0
DCJ17	12318	8	0.94	2	2	0
DCJ18	7707	0	0.47	0.85	1	0
DCJ19	7967	2	0.55	1.05	1	0
DCJ21	7209	8	0.94	2.51	1	1
DCJ24	6863	1	0.82	1.9	1	1
DCJ27	8032	26	0.34	1.11	1	0
DCJ28	9807	6	0.95	2.01	1	1
DCJ31	12145	22	0.73	1.41	2	0
DCJ32	6278	7	0.65	1.3	1	0
DCJ33	7988	1	0.55	1.02	1	1
DCJ38	7274	0	0.4	1.04	1	1
DCJ49	8465	18	0.95	1.94	1	0
DCJ58	7620	5	0.72	1.74	1	1
DCJ59	4005	12	0.64	1.6	1	0

Substation	Peak Load (kVA)	% Underg.	SAIFI calc.	SAIDI calc.	#feeders	# over-loaded feeders
DCJ60	7447	17	1.02	1.98	1	0
DCJ62	8508	2	0.62	1.32	1	1
DCJ65	5650	0	0.71	1.86	1	1
DCJ66	4979	16	1.08	2.28	1	1
DCJ68	11041	2	0.56	1.13	2	1
DCJ69	15717	7	0.74	1.57	2	0
DCJ76	3788	2	0.77	1.77	1	0
DCJ87	7360	12	0.59	1.45	1	0
DCJ92	14786	22	0.68	1.31	2	1
DCK15	3961	7	0.98	1.93	1	0
DCK18	15977	3	1.54	2.62	2	1
DCK19	18467	16	0.51	1.03	3	0
DCK20	15068	9	0.65	1.11	2	2
DCK32	7187	2	1.71	2.39	1	1
DCK33	5477	6	0.45	0.66	1	0
DCK34	7685	4	1.1	2.18	2	0
DCK39	1796	4	1.17	1.86	1	0
DCK42	5412	11	0.29	0.46	1	0
DCK44	5131	2	1.16	1.8	1	0
DCK45	5910	8	0.73	1.39	1	0
DCS11	714	2	0.33	0.68	1	0
DCS14	930	1	0.56	1.81	1	0
DCS15	5044	47	0.31	0.71	1	0
DCS16	2359	0	0.28	0.65	1	0
DCS20	2836	3	0.75	1.51	1	0
DCS21	2662	2	0.92	1.67	1	0
DCS25	974	0	0.55	1.19	1	0
DCS26	1277	0	1.1	2.22	1	0
DCS27	1342	0	0.23	0.71	1	0
DCS29	3139	8	0.9	1.65	1	0
DCS35	1645	0	0.89	2.27	1	0
DCS36	1818	3	0.97	1.92	1	0
DCS37	11171	9	0.49	1.07	2	1
DCS39	6062	13	0.7	1.6	1	0
DCS40	1796	0	1.52	3.32	1	0
DCS41	3420	0	1	1.93	1	0
DCS42	2533	4	0.64	1.48	1	0
DCS43	5715	7	2.12	4	1	1
DCS44	7772	0	0.51	1.08	1	0
DCS47	5910	14	1.05	1.89	1	0
DCS48	6343	1	0.27	0.66	1	0
DCS63	3139	0	0.52	1.51	1	0
DCS66	11950	13	0.5	1.34	2	0
DCS67	3355	0	1.11	1.76	1	0
DCW10	9020	2	0.71	1.39	2	0
DCW102	433	6	0.54	1.07	1	0
DCW115	9238	6	0.66	1.28	2	0

Substation	Peak Load (kVA)	% Underg.	SAIFI calc.	SAIDI calc.	#feeders	# over-loaded feeders
DCW118	7324	6	1.4	2.15	1	0
DCW119	9165	21	0.7	1.63	2	0
DCW12	9006	1	0.69	1.17	1	0
DCW148	4366	0	0.56	1.37	1	0
DCW152	5665	37	0.32	0.66	1	0
DCW16	10435	43	0.41	1.04	2	1
DCW17	4546	9	0.34	0.97	1	0
DCW18	12730	19	0.46	0.98	2	0
DCW19	11835	16	0.7	1.45	2	0
DCW20	7454	20	0.82	1.86	1	1
DCW202	5997	0	0.23	0.58	2	0
DCW211	5629	1	1.5	2.19	1	1
DCW218	6314	23	0.33	0.72	1	0
DCW233	2525	28	0.47	0.94	1	0
DCW236	12773	36	0.29	0.78	3	0
DCW25	6386	8	0.63	1.41	2	0
DCW26	9399	44	0.39	0.93	3	0
DCW28	2525	76	0.05	0.12	1	0
DCW29	12484	27	0.43	1	1	0
DCW30	15523	14	0.58	1.24	2	0
DCW302	10630	19	0.51	1.31	2	0
DCW31	7166	10	0.35	0.78	2	0
DCW33	8587	15	0.75	1.28	1	0
DCW334	5412	0	0.32	0.68	1	0
DCW335	9764	12	0.51	1.13	6	0
DCW336	14137	36	0.72	1.31	2	1
DCW340	6379	32	0.41	1.01	1	0
DCW343	5845	8	0.42	1.01	1	0
DCW346	7433	41	0.78	1.55	1	0
DCW38	15804	34	0.84	1.6	2	0
DCW39	15443	12	1.05	2.12	2	0
DCW41	6061	20	0.62	1.15	1	0
DCW44	5737	82	0.39	0.85	1	0
DCW46	5520	53	0.32	0.93	1	0
DCW48	4835	32	0.24	0.55	1	0
DCW50	10796	45	0.7	1.43	2	0
DCW51	3153	0	0.24	0.57	1	0
DCW64	5629	65	0.21	0.59	1	0
SS249	18063	58	0.43	0.95	3	1
SS284	5123	40	0.32	0.87	1	0
SS311	6812	5	1	2.11	1	1
SS312	1605	0	0.36	1.1	1	0
SS314	15126	11	0.7	1.67	3	1
SS316	19966	10	0.63	1.73	3	1
SS318	12015	100	0.06	0.23	4	0
SS422	16129	10	0.49	1.16	2	1
SS450	5975	4	0.59	1.22	1	0

Substation	Peak Load (kVA)	% Underg.	SAIFI calc.	SAIDI calc.	#feeders	# over-loaded feeders
SS459	13791	15	0.43	1.08	2	1
SS460	10211	3	0.53	1.33	2	1
SS462	6819	13	1.04	1.81	1	0
SS471	14050	4	0.7	1.27	2	0
SS501	5196	5	0.31	0.87	1	0
SS513	25777	21	0.47	1.3	4	1
SS553	13278	15	0.32	0.74	1	1
SS558	26990	35	0.44	1.19	4	0
STA11	161773	90	0.27	0.88	31	2
STA13(2)	213410	82	0.3	0.85	41	3
STA13(3)	98779	76	0.26	0.68	26	0
STA16	15876	19	0.54	1.03	4	0
TDC204	124218	53	1.22	3.2	16	6
TDC205	68154	49	0.68	1.89	11	1
TDC206	131602	72	0.17	0.51	21	7
TDC207	111986	46	0.58	1.63	28	18
TDC212	87335	47	0.86	2.3	16	1
TDC213	194222	63	0.82	2.3	24	8
TDC214	181037	56	0.27	0.75	24	6
TDC215	32133	22	0.62	1.4	8	0
TDC216	75202	32	0.6	1.57	10	2
TDC217	40445	40	0.7	1.65	10	1
TDC220	64199	68	0.16	0.46	10	1
TDC225	57206	49	0.57	1.63	10	3
TDC228	46042	26	0.91	2.09	10	4
TDC230	42060	17	0.81	1.93	7	3
TDC233	65677	21	0.27	0.61	13	0
TDC234	113915	41	0.85	2.14	15	4
TDC235	24522	61	0.41	0.93	7	2
TDC237	80653	65	0.76	2.09	12	1
TDC240	10298	42	0.36	0.82	2	1
TDC248	75486	36	0.83	2.09	12	2
TDC250	13423	12	0.67	1.44	2	0
TDC253	166322	65	0.15	0.41	24	8
TDC258	60648	50	0.67	1.82	10	1
TDC260	69424	32	0.92	2.09	12	1
TDC268	206230	50	0.95	2.94	24	6
TDC282	20177	14	0.79	1.77	6	0
TDC294	91081	47	0.97	2.69	16	6
TDC317	37757	9	0.84	2.1	7	1
TDC370	29769	30	0.82	2.27	4	2
TDC372	16576	19	0.68	1.41	3	3
TDC375	60730	26	0.75	1.94	11	2
TDC380	52320	7	0.52	1.54	8	6
TDC384	38197	22	0.59	1.59	10	1
TDC385	16324	4	0.27	0.72	3	1
TDC386	13942	3	0.85	2.22	2	0

Substation	Peak Load (kVA)	% Underg.	SAIFI calc.	SAIDI calc.	#feeders	# over-loaded feeders
TDC387	38298	22	0.79	1.99	7	0
TDC388	58108	15	0.77	2.13	10	0
TDC389	31067	48	0.53	1.3	5	0
TDC411	62070	38	0.67	1.94	8	2
TDC414	74237	24	0.68	1.71	11	2
TDC416	81209	31	0.71	1.82	9	5
TDC419	188008	59	0.55	1.68	31	5
TDC431	19918	6	0.59	1.47	2	2
TDC435	95230	36	0.72	2.13	14	1
TDC436	111649	30	0.71	1.81	17	2
TDC439	49751	25	0.76	1.8	8	0
TDC440	69590	20	0.59	1.57	10	1
TDC443	61139	19	0.63	1.75	11	0
TDC446	67504	18	0.73	1.87	10	3
TDC447	30807	25	0.52	1.15	5	1
TDC451	60996	29	0.79	2.09	7	4
TDC452	93246	17	0.78	2.16	13	3
TDC453	52089	27	0.48	0.91	10	1
TDC454	32864	18	0.8	1.96	5	1
TDC456	37627	23	0.62	1.29	7	2
TDC457	55813	23	0.71	1.72	8	1
TDC458	59061	26	0.64	1.75	12	1
TDC461	134627	18	0.83	2.33	18	7
TDC465	94350	13	0.6	1.69	15	5
TDC469	68551	24	0.55	1.5	11	4
TDC474	46429	11	0.85	1.96	7	3
TDC487	34336	11	0.91	1.89	5	2
TDC505	71250	40	0.58	1.48	13	0
TDC517	34825	12	0.83	1.76	5	3
TDC531	65901	19	0.91	2.12	11	2
TDC539	41676	54	0.58	1.27	8	1
TDC549	54341	10	0.53	1.41	9	1
TDC550	80321	14	0.4	1.13	13	4
TDC552	54009	21	0.69	1.66	7	2
TDC555	70073	28	0.71	1.85	11	0
TDC556	27495	49	0.4	0.94	6	1
TDC557	76288	59	0.6	1.65	11	5
TDC559	72014	52	0.61	1.81	11	2
TDC560	71711	15	0.58	1.36	13	1
TDC561	124631	62	0.78	2.39	18	4
TDC562	163984	62	0.63	1.77	25	7
TDC563	68154	23	0.74	2.05	10	3
TDC565	76215	42	0.62	1.63	13	4
TDC566	155605	66	0.65	1.72	28	6
TDC568	65231	28	0.71	1.9	10	3
TDC569	30432	20	1.11	2.22	5	0
TDC570	138444	39	0.88	2.34	20	3

Substation	Peak Load (kVA)	% Underg.	SAIFI calc.	SAIDI calc.	#feeders	# over-loaded feeders
TDC572	50386	42	0.73	1.93	9	1
TDC574	164864	51	0.58	1.6	21	7
TDC577	50694	30	0.59	1.47	1	3
TDC580	110401	52	0.6	1.8	18	5
TDC581	137628	57	0.76	2.23	23	1
TDC592	18601	18	0.74	1.89	3	1
TDC593	37281	32	0.76	1.69	8	2
TDC595	127092	46	0.63	1.76	19	4
TDC648	119291	39	0.37	1.01	20	3
TDC714	123606	82	0.21	0.59	27	1
TDC745	176316	95	0.27	0.8	31	1
TDC784	120494	76	0.16	0.53	24	1
TDC785	241244	99	0.27	0.91	33	7
TDC814	47630	17	0.5	1.39	8	2
TDC840	125528	87	0.35	0.97	33	0
TSS101	130807	54	0.7	1.85	18	5
TSS102	125859	40	0.83	2.37	29	6
TSS103	142175	49	0.89	2.33	22	5
TSS104	76619	55	0.33	1.03	13	0
TSS106	68226	17	0.85	2.17	10	3
TSS109	94690	50	0.69	2.04	12	2
TSS110	49535	61	0.3	0.8	14	1
TSS114(1)	189279	82	0.28	1.02	27	4
TSS114(2)	109240	87	0.32	1.15	21	3
TSS114(3)	146376	76	0.33	1.19	26	6
TSS114-FKL	23465	100	0.12	0.55	4	0
TSS115	6848	29	0.33	0.77	2	0
TSS117	74144	54	0.62	1.73	12	1
TSS118	80572	41	0.34	1.04	15	1
TSS120	57228	19	0.73	1.86	10	3
TSS121	24291	9	0.88	2.17	5	1
TSS122	36321	5	0.8	2.1	6	1
TSS123	2554	7	0.83	2.64	1	0
TSS127	77809	41	0.62	1.72	14	2
TSS129	96618	37	0.64	1.69	19	3
TSS131	85091	25	0.79	2.08	13	0
TSS132	5058	0	0.87	2.69	2	0
TSS133	5434	11	0.85	2.39	1	1
TSS134	104785	18	0.8	2.22	16	5
TSS135	31753	39	0.51	1.22	5	1
TSS136	169158	44	0.7	1.94	26	4
TSS137	212026	76	0.46	1.16	38	1
TSS138	8587	29	0.79	1.52	1	0
TSS140	76489	19	0.77	2.06	11	4
TSS145	183657	57	0.54	1.48	23	5
TSS149	8010	0	0.59	1.38	1	0
TSS150	252742	73	0.3	0.94	44	2

Substation	Peak Load (kVA)	% Underg.	SAIFI calc.	SAIDI calc.	#feeders	# over-loaded feeders
TSS151	110775	24	0.92	2.57	15	5
TSS152	171649	44	0.57	1.56	24	1
TSS154	107853	37	0.96	2.54	17	3
TSS157	63975	12	0.51	1.06	10	4
TSS160	86325	47	0.61	1.84	16	0
TSS162	48394	5	0.97	2.34	10	0
TSS163	94156	12	0.78	2.04	16	7
TSS164	68558	24	0.54	1.61	14	0
TSS165	78914	18	0.63	1.66	16	5
TSS166	192468	56	1.13	3.42	29	6
TSS172	172701	36	0.58	1.6	27	4
TSS174	107768	87	0.3	0.76	17	2
TSS193	69333	24	0.76	2.03	11	3
TSS194	47088	14	0.62	1.7	11	4
TSS198	77541	52	0.61	1.33	28	0
TSS30(1)	42918	79	0.19	0.49	14	1
TSS30(2)	51440	72	0.25	0.75	11	1
TSS31	111776	63	0.3	0.9	24	2
TSS32	88976	70	0.32	0.89	22	0
TSS33	79239	53	0.29	0.82	19	1
TSS34	83406	58	0.27	0.88	12	3
TSS35	111120	93	0.25	0.8	19	1
TSS37	88554	32	0.34	0.92	14	3
TSS38	184314	79	0.34	0.95	43	2
TSS39(1)	109240	55	0.22	0.61	19	1
TSS39(2)	73372	60	0.32	0.89	12	1
TSS41	82829	61	0.3	0.84	16	1
TSS42	68998	21	0.78	1.92	12	2
TSS43	48734	59	0.27	0.67	16	0
TSS44	40383	94	0.33	0.97	10	0
TSS45	201389	88	0.24	0.76	30	2
TSS46	60630	24	0.79	1.95	16	0
TSS47	86729	71	0.56	1.57	18	2
TSS48	43292	24	0.53	1.42	7	1
TSS49	39653	100	0.18	0.62	6	1
TSS51	71039	15	0.91	2.44	11	3
TSS52	50682	31	0.51	1.43	8	0
TSS54	181466	81	0.35	1.06	31	3
TSS55	54852	19	0.33	0.85	10	1
TSS56	98276	20	1	2.59	15	5
TSS57	62416	40	0.41	1.19	13	2
TSS59	37541	15	0.45	1.04	8	0
TSS60	164865	28	0.71	2.05	22	7
TSS63	132779	59	0.38	1.02	24	1
TSS64	89449	21	0.62	1.54	12	2
TSS65	18893	99	0.27	0.94	11	1
TSS68	74800	99	0.3	0.84	16	2

Substation	Peak Load (kVA)	% Underg.	SAIFI calc.	SAIDI calc.	#feeders	# over-loaded feeders
TSS69	10680	20	0.56	1.09	2	0
TSS70	91124	31	0.96	2.44	12	4
TSS71	156009	60	0.31	0.83	25	3
TSS75	111165	29	0.95	2.68	16	4
TSS76	65253	6	0.74	1.7	11	2
TSS78	102750	17	0.7	1.93	18	3
TSS79	15270	24	0.63	1.41	2	1
TSS82	296727	95	0.3	0.97	41	7
TSS83	39387	13	0.82	1.92	6	0
TSS84	204951	70	0.28	0.84	33	4
TSS85	41957	58	0.47	1.32	8	0
TSS87	99597	100	0.17	0.57	15	4
TSS88	88786	34	0.58	1.72	16	0

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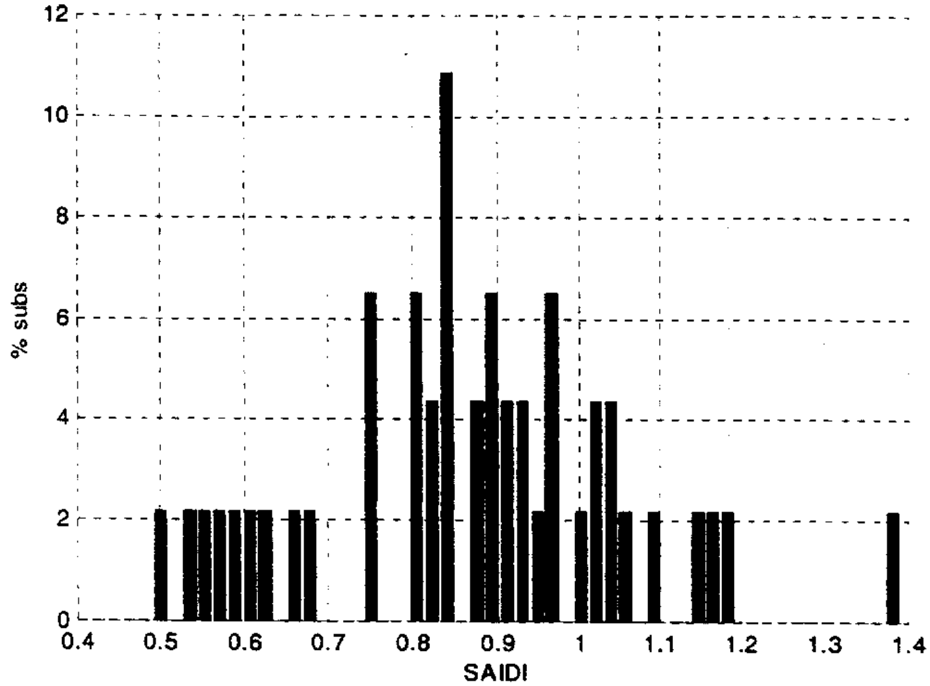


Figure 7. Histogram showing predicted SAIDI distribution for Chicago substations.

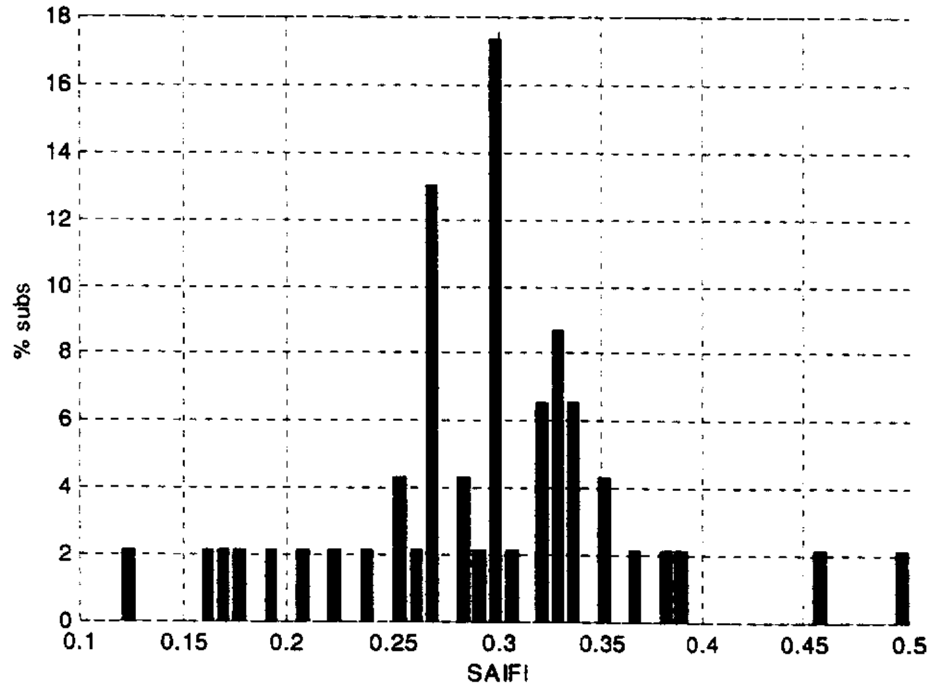


Figure 8. Histogram showing predicted SAIFI distribution for Chicago substations.

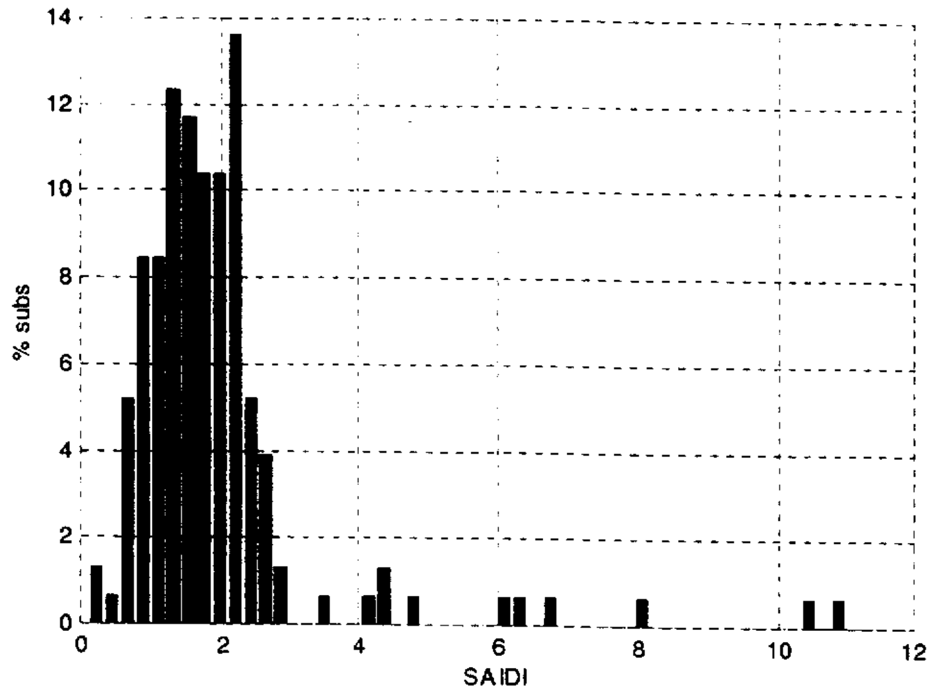


Figure 9. Histogram showing predicted SAIDI distribution for Northwest substations.

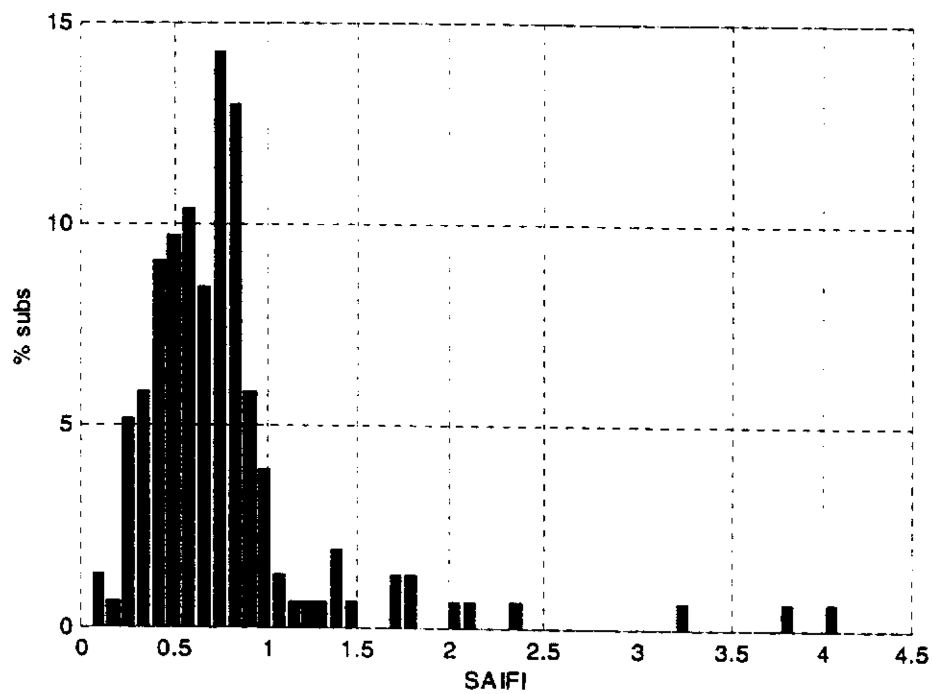


Figure 10. Histogram showing predicted SAIFI distribution for Northwest substations.

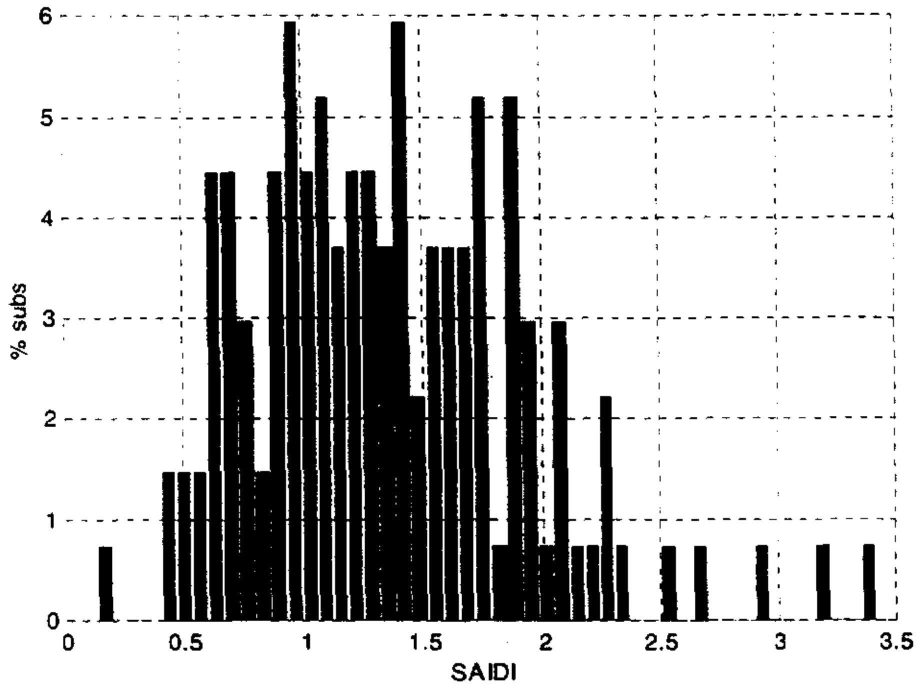


Figure 11. Histogram showing predicted SAIDI distribution for Northeast substations.

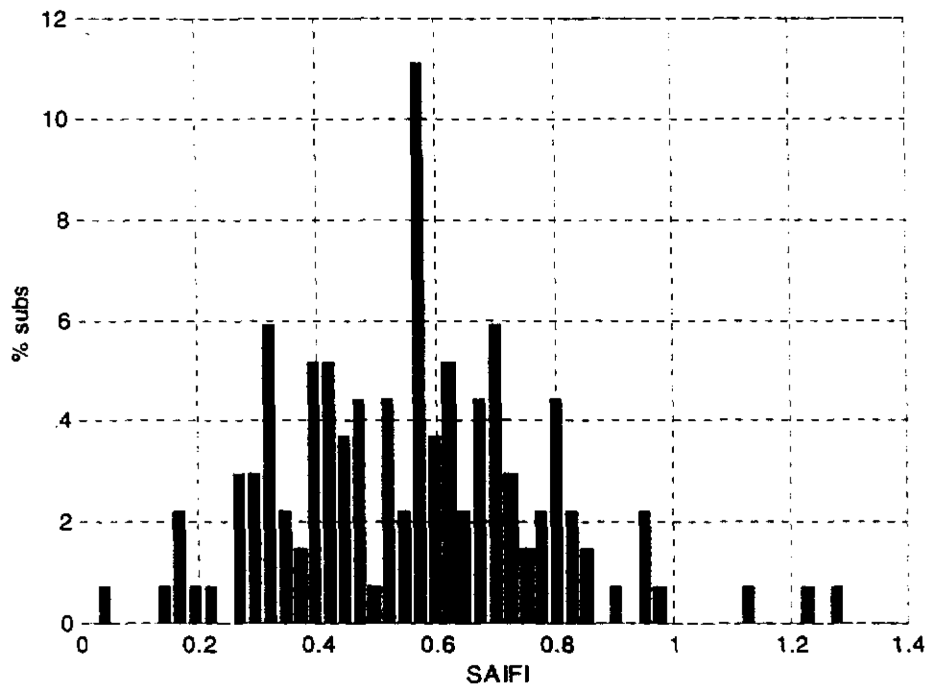


Figure 12. Histogram showing predicted SAIFI distribution for Northeast substations.

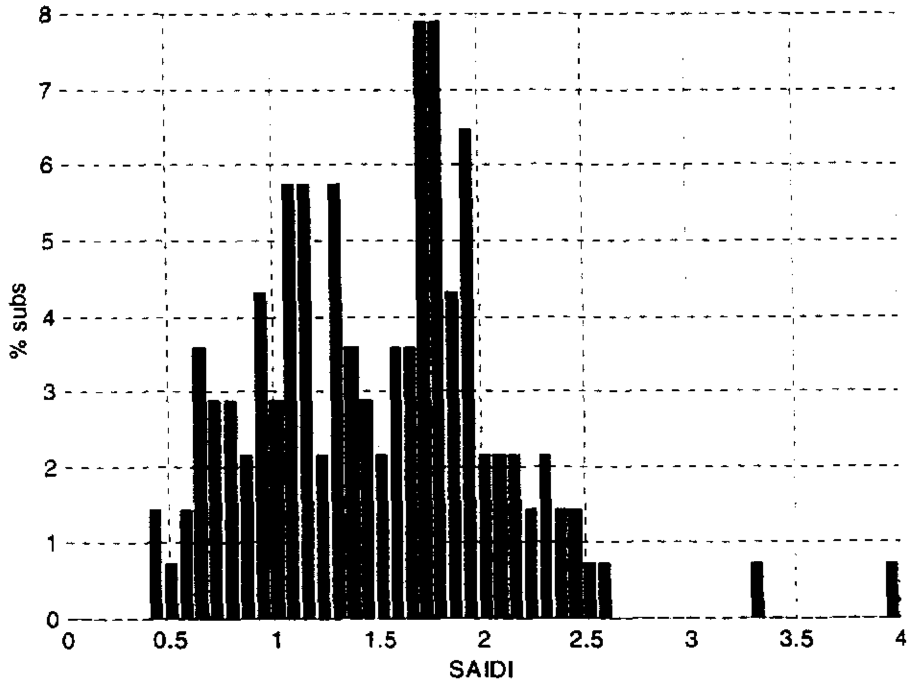


Figure 13. Histogram showing predicted SAIDI distribution for Southern substations.

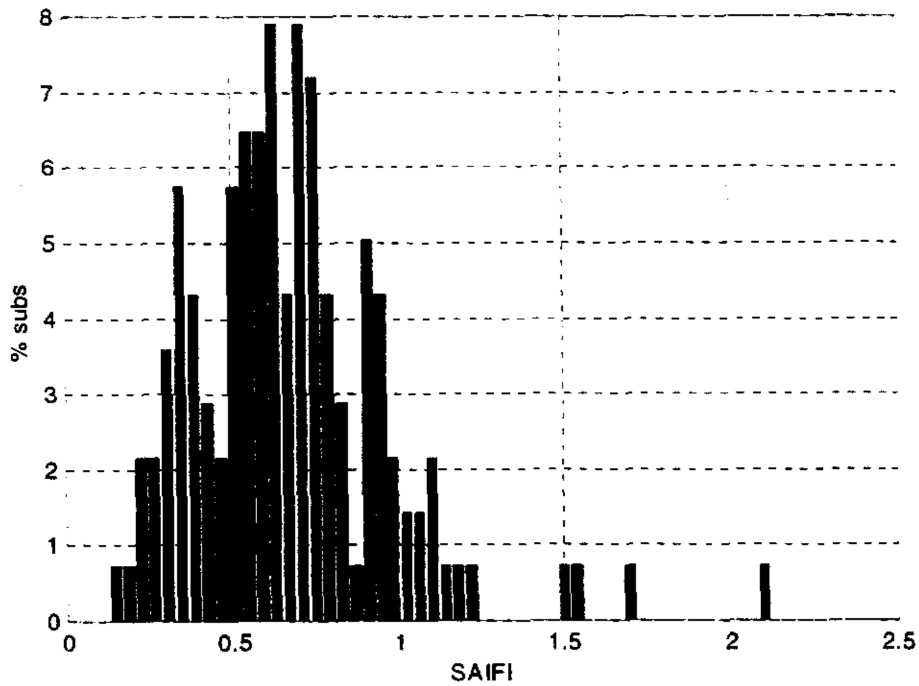


Figure 14. Histogram showing predicted SAIFI distribution for Southern substations.

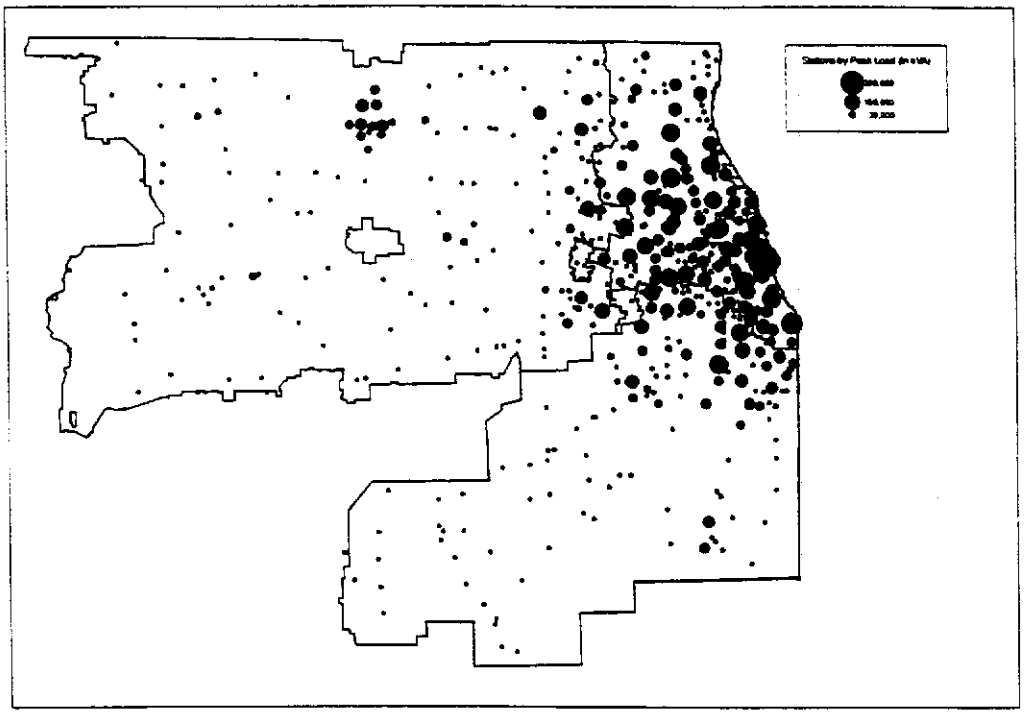


Figure 15. Location and size of peak loads on ComEd system.

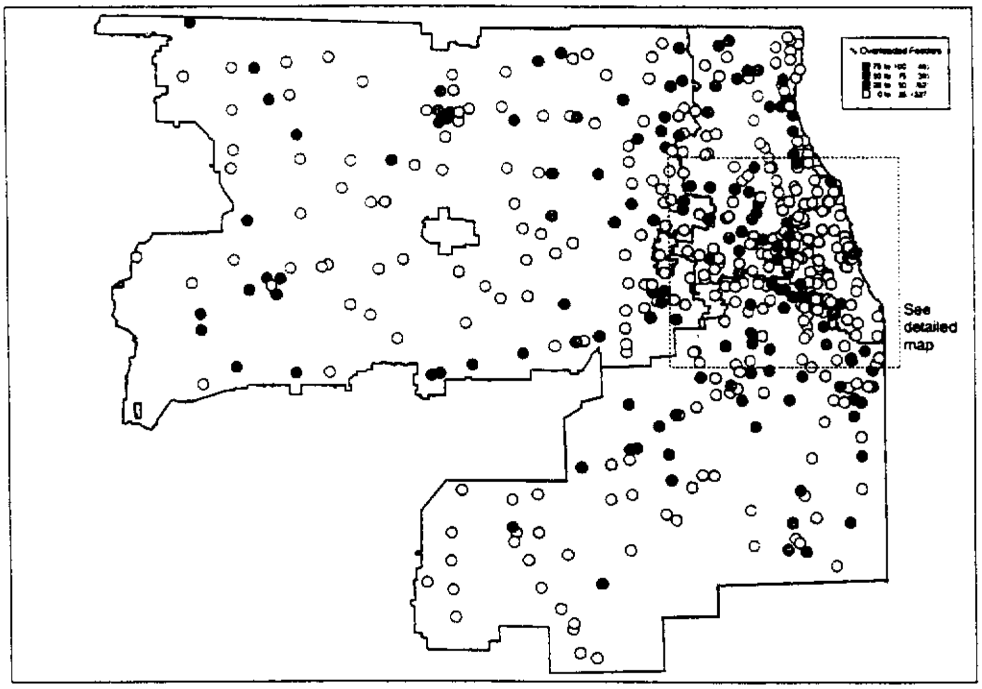


Figure 16. Location and size of overloaded feeders on ComEd system.

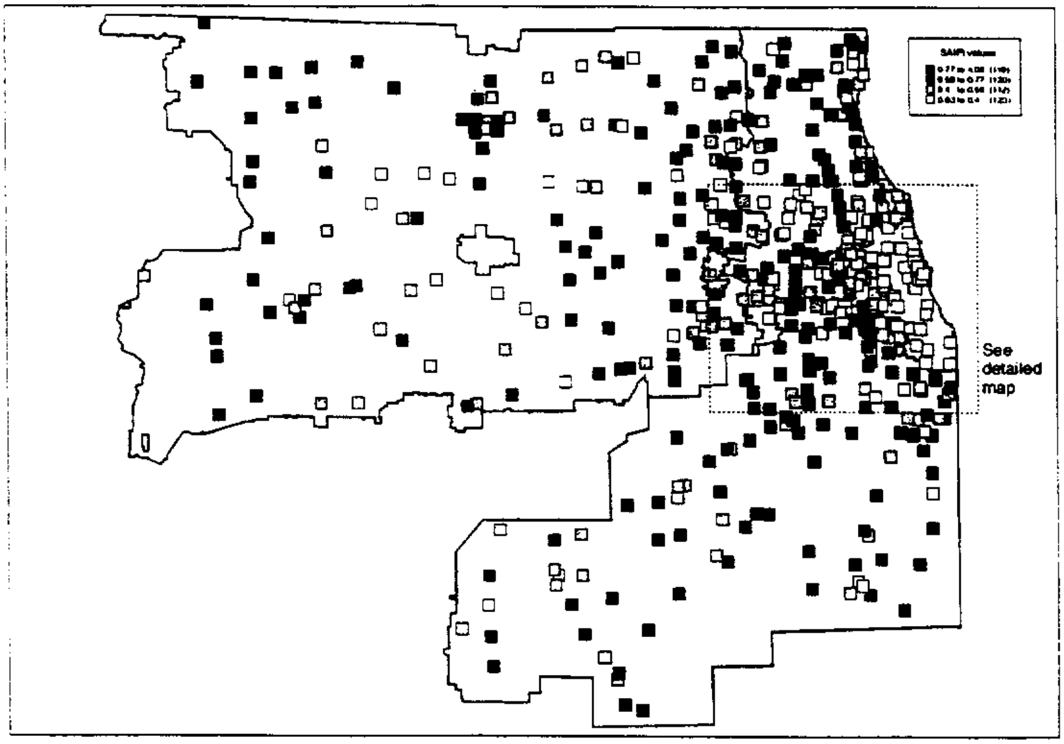


Figure 17. Visualization of SAIFI on ComEd system.

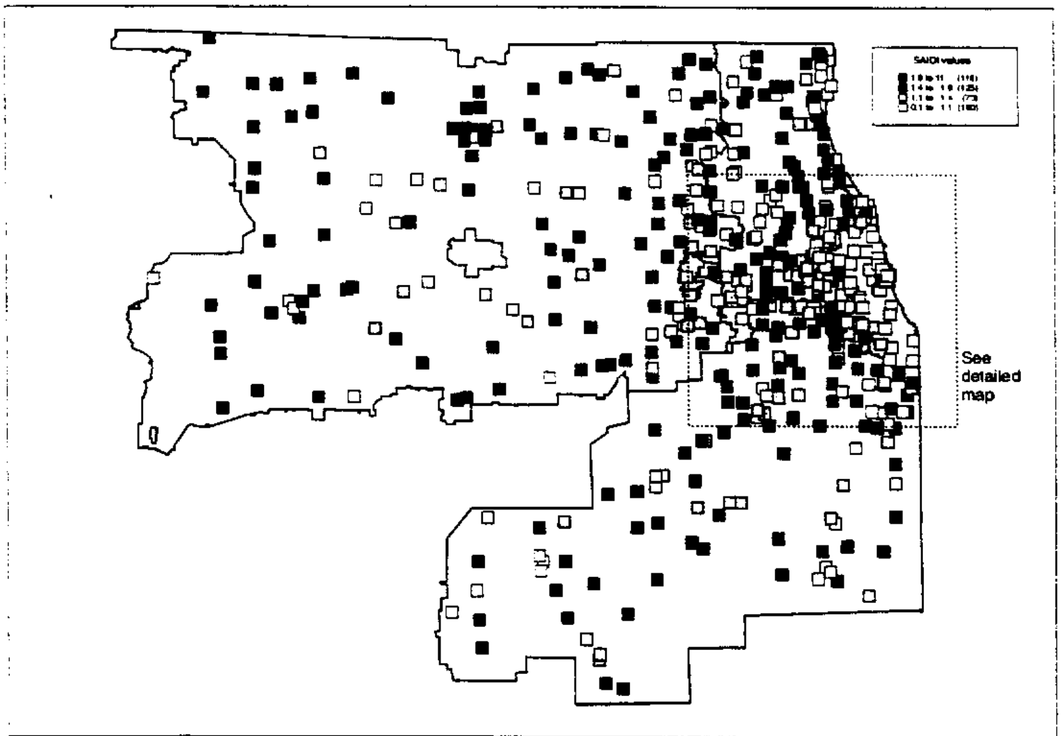


Figure 18. Visualization of SAIDI on ComEd system.

3.3 Reliability Recommendations

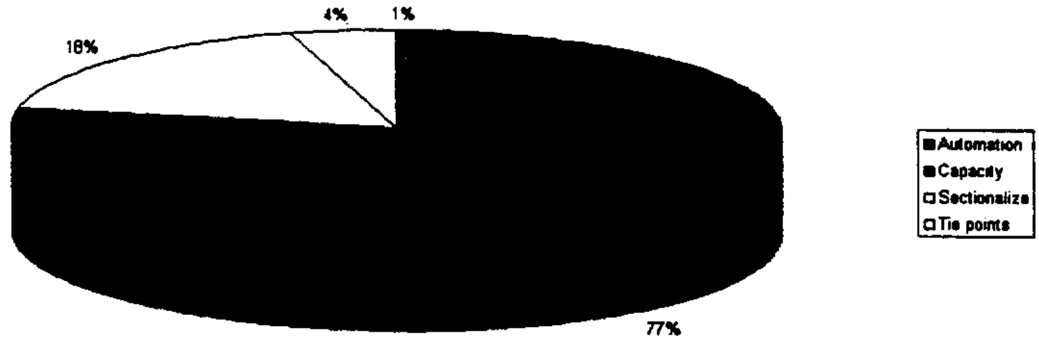


Figure 19. Breakdown of the top 10% of recommendations by type.

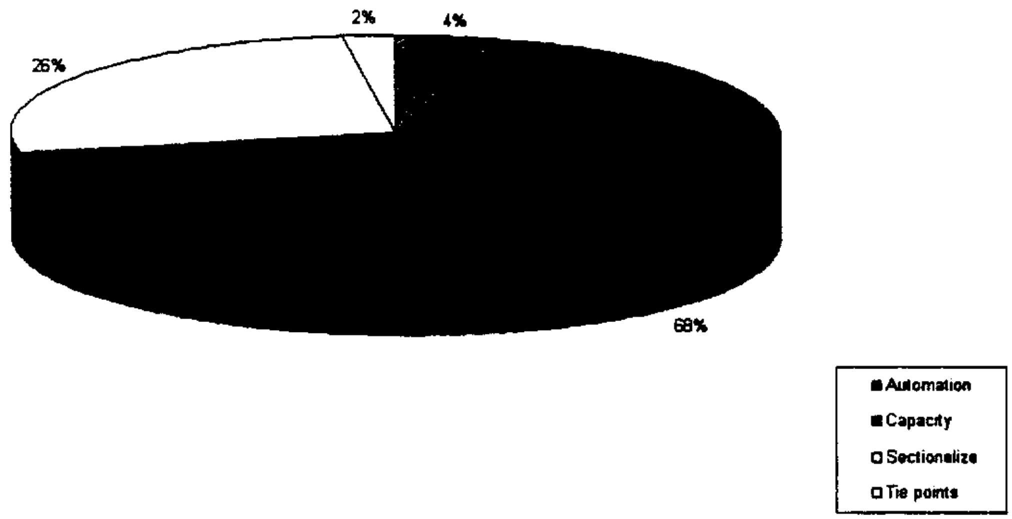


Figure 20. Breakdown of all of recommendations by type.

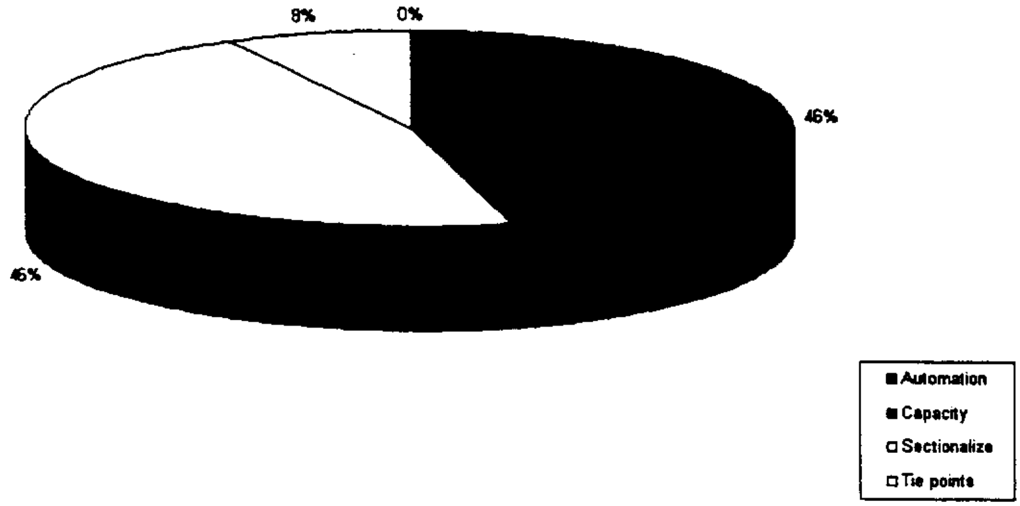


Figure 21. Breakdown of all of recommendations by type for Chicago area.

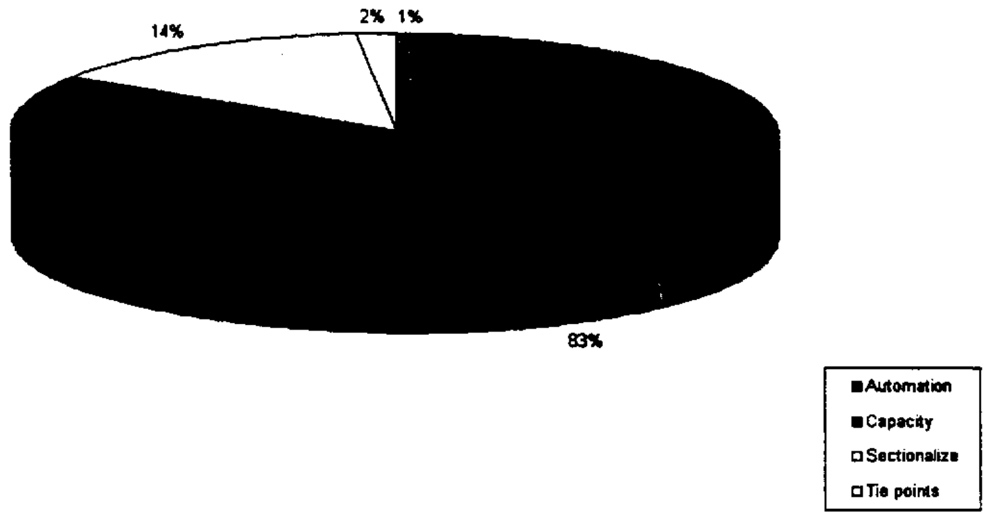


Figure 22. Breakdown of all of recommendations by type for Northeast area.

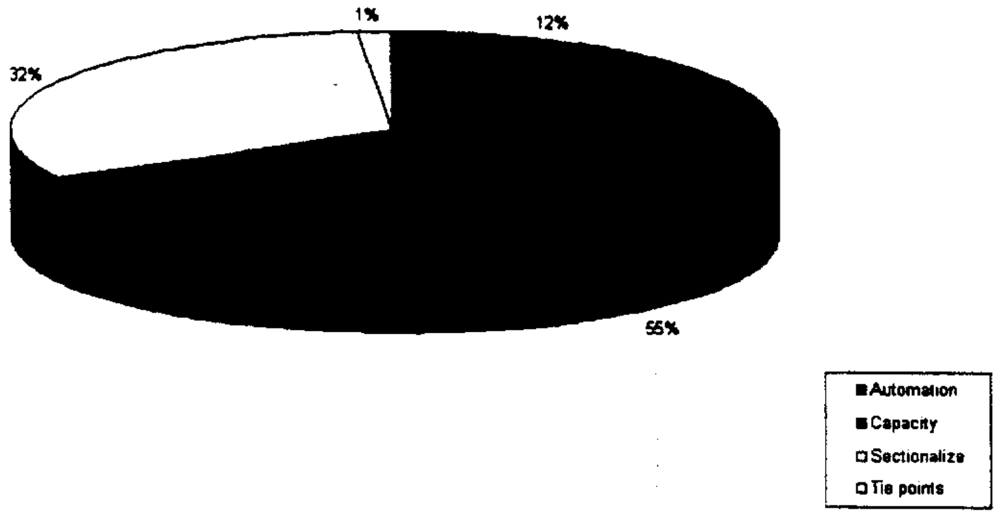


Figure 23. Breakdown of all of recommendations by type for Northwest area.

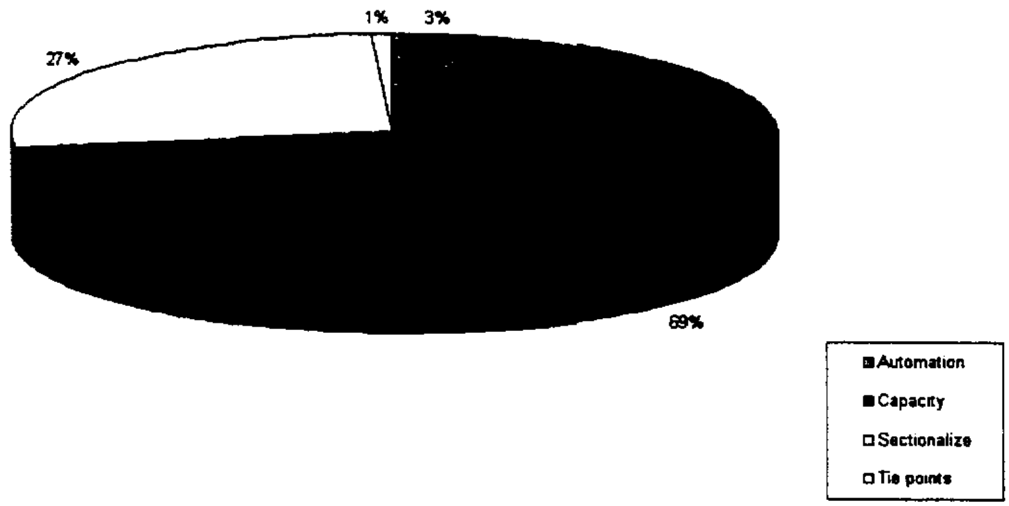


Figure 24. Breakdown of all of recommendations by type for Southern area.

Appendix A – Reliability Assessment Methodology

Distribution system reliability is quickly becoming one of the most important subjects in the electric power industry. This is driven by several factors including (1) the increasing sensitivity of customer loads to poor reliability, (2) the importance of distribution systems to customer reliability, (3) the large costs associated with distribution systems, and (3) regulatory motions towards customer choice and performance based rates. In the past, distribution system reliability was a by-product of standard design practices and reactive solutions to historical problems. In the future, distribution system reliability will be a competitive advantage that must be planned for, designed for, optimized and treated with analytical rigor.

In the same manner that a power flow model can predict the electrical behavior of a distribution system (such as currents and voltages), a reliability assessment model can predict the reliability behavior of a distribution system (such as interruptions and outages). As reliability becomes more important to electric utilities and electricity consumers, these reliability assessment models will equal or surpass power flow models in importance and usage. Reliability models allow distribution engineers to:

- Design new systems to meet explicit reliability targets
- Identify reliability problems on existing systems
- Test the effectiveness of reliability improvement projects
- Determine the reliability impact of system expansion
- Design systems that can offer different levels of reliability
- Design systems that are best suited for performance based rates

There are four common methodologies used for distribution reliability assessment: network modeling, Markov modeling, analytical simulation and Monte Carlo simulation. A brief description of each is provided below.

Network Modeling translates a physical network into a reliability network based on serial and parallel component connections. This method is simple and straightforward to implement, but cannot easily handle complex switching behavior and sequential system responses to contingencies.

Markov Modeling is a powerful method based on system states and transition rates between these states. This method has two disadvantages when applied to distribution system reliability assessment. The first limitation is that states are memoryless (transition out of a state cannot depend on how the state was reached). This characteristic requires duplication of states when system responses are a function of past events. The second limitation is computational. The matrix inversion required by Markov modeling limits the size of systems that can be represented and/or the complexity that can be represented.

Analytical Simulation models each system contingency, computes the impact of each contingency, and weights this impact based on the expected frequency of the contingency. This method can accurately model complex system behavior and dynamically enumerates each possible system state.

Monte Carlo Simulation is similar to analytical simulation, but models random contingencies rather than expected contingencies. This allows component parameters to be modeled with probability distribution functions rather than expected values. Monte Carlo Simulation can model complex system behavior, non-exclusive events and produces a distribution of possible results rather than expected values [5]. Disadvantages include computational intensity and imprecision (multiple analyses on the same system will produce slightly different answers). In addition, Monte Carlo Simulation is not enumerative and may overlook rare but important system states.

For applications requiring expected values, analytical simulation is the best method for distribution system reliability assessment. This allows distribution engineers to quantify system reliability, calibrate models to historical data, compare design alternatives, perform sensitivity analyses and run optimization algorithms. An analytical simulation was used for all of the results in the Commonwealth Edison feeder analysis study.

An analytical simulation simulates a contingency, determines the impact of this contingency on system reliability, and weights the impact of the contingency by its probability of occurrence. This process is repeated for all possible contingencies, and results in the following information for each component:

Results of an Analytical Simulation

1. Expected number of momentary interruptions (per year)
2. Expected number of Sustained interruptions (per year)
3. Expected number of interrupted hours (per year)
4. Expected number of protection device operations (per year)
5. Expected number of switching operations (per year)

A contingency occurring on a distribution system is followed by a complicated sequence of events. Because of this, each contingency may impact many different customers in many different ways. In general, the same fault will result in momentary interruptions for some customers and varying lengths of sustained interruptions for other customers depending on how the system is switched and how long the fault takes to repair. The key to an analytical simulation is to accurately model the sequence of events after a contingency to capture the different consequences for different customers. A generalized sequence of events is:

Analytical Simulation: Sequence of Events After a Fault

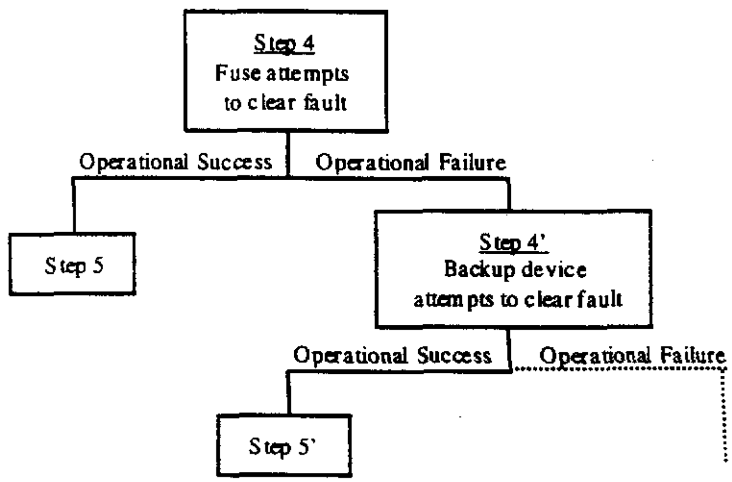
1. **Contingency:** A fault occurs on the system
2. **Reclosing:** A reclosing device opens in an attempt to allow the fault to clear. If the fault clears, the reclosing device closes and the system is restored to normal.
3. **Automatic Sectionalizing:** Automatic sectionalizers that see fault current attempt to isolate the fault by opening when the system is de-energized by a reclosing device.
4. **Lockout:** If the fault persists, time overcurrent protection clears the fault. Lockout could be the same device that performed the reclosing function, or could be a different device that is closer to the fault.
5. **Automated Switching:** Automated switches are used to quickly isolate the fault and restore power to as many customers as possible. This includes both upstream restoration and downstream restoration. In upstream restoration, a sectionalizing point upstream from the fault is opened. This allows the protection device to reset

and restoration of all customers upstream of the sectionalizing point. In downstream restoration, other sections that remain de-energized are isolated from the fault by opening switches. Customers downstream from these points are restored through alternate paths by closing normally-open tie switches.

6. **Manual Switching:** Manual switching restores power to customers that were not able to be restored by automated switching (certain customers will not be able to be restored by either automated or manual switching). As in automated switching, manual switching has both an upstream restoration component and a downstream restoration component.
7. **Repair:** The fault is repaired and the system is returned to its pre-fault state.

The seven steps outlined above generate a set of system states for each contingency. These states are characterized by switches and protection devices being open or closed. For each state occurring with frequency □□and duration □, the accrued outage frequency of all de-energized components are incremented by □ (if the component was energized in the preceding state) and the accrued outage duration of all de-energized components are incremented by $\lambda \cdot \delta$.

The analytical simulation sequence of events becomes more complicated if operational failures are considered. Operational failures occur when a device is supposed to operate, but fails to do so. The probability of such an event is termed *probability of operational failure*, *POF*. Operational failures cause the simulation sequence to split. One path assumes that the device fails to operate and has a weight of *POF*, the other path assumes that the device operates and has a weight of 1 –*POF*. This path splitting is illustrated in Figure A2-1 by considering a fuse that is supposed to clear a fault.



Simulation Path Splitting Due to Operational Failures

The result of simulation path splitting is an enumerative consideration of all possible system responses to each contingency (in the context of operational failures). Enumerative consideration is important since some states may be rare, but have a major impact on the system when they do occur. During restoration, path splitting associated with the enumerative consideration of possible outcomes is important when intended switching fails and customers that would otherwise have been restored are not.

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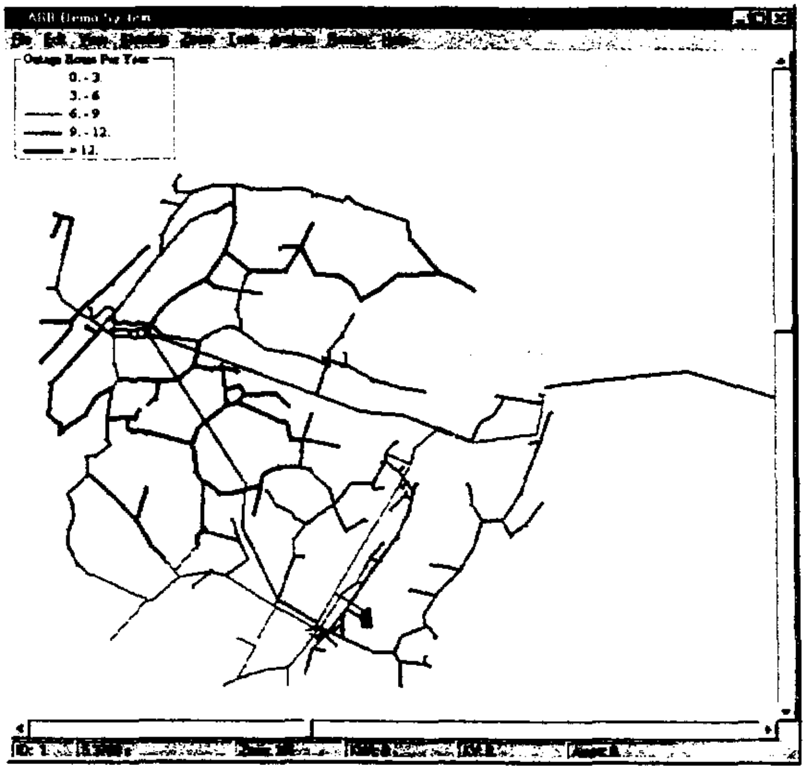
An analytical simulation is now demonstrated on a test system based on an actual U.S. utility distribution system. The system model contains 3 voltage levels, 4 substations, more than 200 miles of feeder, and approximately 2000 system components. The figure is shaded based on computed outage hours, with dark areas having more expected outage time than light areas.

Individual component reliability results can be easily used to generate a host of reliability indices. For this system, common indices include:

MAIFI (Momentary Average Interruption Frequency Index)	=	4.55 /yr
SAIFI (System Average Interruption Frequency Index)	=	3.19 /yr
SAIDI (System Average Interruption Frequency Index)	=	8.02 hr/yr



Results of an Analytical Simulation

An analytical simulation will produce identical results if an analysis is performed multiple times. In addition, small changes in input data will result in small changes to results. This allows the impact of small reliability improvements to be quantified for individual customers and reliability indices. It also allows input parameters to be perturbed and result sensitivities to be computed.

SA	Sq	Station	Name	Connected 12kV Stations (* "may include others")									
C_10	C2	TSS172	Golf Mill	TDC216	TSS46	TSS198	DCC80	TSS129	C629	TDC216	DCC97	TSS117	TDC212
C_10	C1	TSS46	Des Plaines	TSS152	TDC215	TDC216	TSS198	TSS172	DCC97				
C_2	C2	DCC34	Braiside	TDC212									
C_2	C2	DCC73	Techny	TDC213	TDC212								
C_2	C2	TDC212	Northbrook	DCC73	TSS172	TDC213	TDC258	TSS48	DCC34	DCC3			
C_2	C2	TDC213	Deerfield	TSS48	TSS117	TDC212	TDC237	DCC73	DCC85	TSS172			
C_3	C2	DCC85	Skokie	TDC205	TSS117	TDC213							
C_3	C1	TDC216	Mount Prospect	TSS172	TSS46	TSS117	TDC268	TDC217					
C_3	C1	TDC217	Prospect Heights	TDC205	TDC216	TSS117							
C_3	C1	TSS117	Prospect Heights	TDC205	TDC268	TDC216	TDC213	TSS172	DCC85	TDC217			
C_4	C2	DCC20	Evanston	TSS47	SS249	DCC61							
C_4	C2	DCC61	Garnett	DCC53	TSS47	DCC20							
C_4	C2	SS249	Wilmette SS	DCC20	TDC258	TSS47							
C_4	C2	TDC258	Elmwood	TSS172	TDC212	TSS88	SS249						
C_4	C2	TSS47	Evanston	DCC61	TSS85	DCC53	DCC66	DCC20	TSS88	SS249			
C_4	C2	TSS88	Skokie	TSS47	TDC258	TSS129	DCC60						
C_5	C2	DCC33	Niles	TSS129	DCC91								
C_5	C2	DCC53	Evanston	DCC61	TSS47	TSS85							
C_5	C2	DCC60	Skokie	TSS85	TSS88								
C_5	C2	DCC66	Evanston	TSS47									
C_5	D	DCC91	Park Ridge	DCC33	TSS71								
C_5	C2	DCC97	Park Ridge	TSS172	TSS198	TSS46							
C_5	C2	TDC215	Howard	TSS46	TSS196	TSS198							
C_5	C2	TSS129	Niles	DCC33	TSS172	TSS88							
C_5	C2	TSS198	Des Plaines	TSS46	TDC215	TSS172	DCD63	TSS152	TDC648	DCD179	TSS71		
C_5	C2	TSS85	Skokie	TSS47	DCC53	DCC60	TSS110						
C_6	C1	TDC268	Arlington Heights	TSS117	TSS109	TDC216	TSS152	TSS102	DCE69	TDC205			
C_7	C1	DCE12	Palatine	no tie									
C_7	C1	DCE69	Palatine TWP	TSS102	TDC206	TDC268							
C_7	H1	TSS102	Palatine	TDC214	TDC268	TDC253	TDC233	TDC248	DCE69	TDC206			
C_8	C1	TDC206	Rolling Meadows	TDC253	TSS152	DCE69	TSS102						
C_8	H2	TDC214	Hoffman Estates	TDC563	TDC574	TDC220	TDC235	TDC253	TSS102	TDC260			
C_8	H2	TDC220	South Schaumburg	TDC214	TDC253	DCE08	TDC574	DCW236					

SA	Sq	Station	Name	Connected 12kV Stations (* "may include others")									
C_8	H2	TDC253	Schaumburg	TDC206	TDC214	TSS102	DCE08	TDC207	TDC565	TSS152	TDC220		
C_9	C1	TDC207	Tonne	TSS101	TDC225	TDC253	TSS152						
C_9	C1	TDC225	Landmeier	TDC207	TSS152	TSS101							
C_9	C1	TSS152	Busse	TDC206	TDC268	TDC225	TSS46	TDC207	TDC253	TSS198			
D_1	J2	TDC565	Nordic	TDC560	TSS101	DCW346	TDC253	TDC562	DCW236				
D_1	J2	TSS101	Itasca	TDC207	TDC565	TDC552	TDC568	TDC225					
D_2	D	DCD133	River Grove	DCD99	DCD67	DCD87							
D_2	D	DCD17	Winston Park	TSS64	DCD20								
D_2	D	DCD175	Schiller Park	TSS78									
D_2	D	DCD187	Maywood	TSS57									
D_2	D	DCD20	Melrose Park	DCD17	TSS64								
D_2	D	DCD63	Schiller Park	TSS198	TSS78	TDC648							
D_2	D	DCD67	Leyden TWP	TSS64	DCD99	DCD87	DCD133						
D_2	D	DCD87	Leyden	TSS64	DCD67	TDC505	DCD133						
D_2	D	DCD99	Franklin Park	TSS78	DCD67	DCD133							
D_2	D	TDC505	Oak Park	TDC556	TSS59	TSS57	DCD87						
D_2	D	TSS57	Forest Park	DCD69	TDC505	TSS134	DCD187	TDC556					
D_2	D	TSS59	Cicero	TSS52	TSS59								
D_2	D	TSS64	Bellwod	TDC549	DCD20	DCD87	TSS78	DCD67	DCD46	DCD47	DCD62	DCD17	DCD80
D_2	D	TSS78	Franklin Park	DCD99	DCD63	TSS64	DCD46	DCD175	TDC549	TSS135			
D_3	D	DCD46	North Lake	TDC549	TSS64	TSS78							
D_3	D	DCD62	Hillside	TDC549	TSS64	TSS134	DCD80	DCD47					
D_3	D	DCW343	Elmhurst	SS501	TDC566								
D_3	D	SS501	Elmhurst SS	DCW343	TDC549								
D_3	D	TDC549	Berkeley	TSS64	TSS135	TDC568	DCD46	TSS78	DCD62				
D_3	D	TDC568	Church Road	TDC552	TSS135	TDC549	TSS101						
D_3	D	TSS135	Elmhurst	TSS78	TDC568	TDC549							
D_4	J1	DCW334	Villa Park	TSS145	TDC566	TDC552							
D_4	J2	DCW346	Addison	TDC552	TDC565								
D_4	J2	TDC552	Addison	TDC560	TSS145	TDC568	TSS101	DCW346	DCW334				
D_4	J2	TDC560	Grace	TDC552	TDC565								
D_4	J2	TSS120	Lombard	TDC560	TSS145	TDC562	TDC555	TDC595					
D_5	J2	TDC562	Glendale Heights	TDC565	TDC595	TDC574	DCW236						
D_5	J2	TDC595	Pleasant Hill	DCW30	DCW336	TDC574	DCW31	TDC562	TDC539	TSS131	TSS120		
D_6	D	DCD47	Broadview	DCD62	TSS134	TSS64	DCD80						
D_6	D	DCD69	Broadview	TDC556	TSS134	DCD80	TSS57						

SA	Sq	Station	Name	Connected 12kV Stations (* "may include others")									
D_5	D	DCD80	Broadview	TSS134	DCD62	TSS64	DCD69	DCD47					
D_6	D	TDC566	Oakbrook	TDC549	SS553	TSS145	SS558	DCW48	DCW343	DCW334	TSS134		
D_6	D	TSS134	La Grange Park	DCD80	DCD69	TSS57	TSS51	DCD62	TSS136	DCD16	DCD47	TDC566	
D_7	E2	DCD114	Stickney TWP	TDC550	TDC517	DCD244	TSS115	DCG78					
D_7	E2	DCD13	Forest View	DCD255									
D_7	E2	DCD244	Stickney TWP	DCD114	TDC550	DCG78							
D_7	E2	DCD255	Forest View	TSS51	DCD13								
D_7	E1	DCD351	Hodgkins	TSS136	TDC593	TSS51							
D_7	E2	DCD40	Summit	TDC550	TSS51	DCD242	TDC517						
D_7	E2	TDC550	Clearing	TSS51	TSS115	DCD40	DCD114	TDC517	DCD244				
D_7	D	TDC556	Berwyn	TSS52	TSS57	DCD69	TDC505	TSS51					
D_7	E2	TSS115	Bedford Park	TDC550	TDC517	DCD114							
D_7	E2	TSS51	Mc Cook	TSS134	DCD229	TSS52	TDC556	TDC550	DCD40	TDC593	DCD255	DCD351	
D_7	D	TSS52	Hawthorne	TSS51	TDC556	TSS59							
D_8	E2	DCD242	Lyon TWP	TDC517	DCD40	TDC593							
D_8	E2	DCG121	Worth	TDC414	TDC440								
D_8	E2	DCG42	Worth TWP	TDC531	TDC414	TSS60							
D_8	E2	DCG78	Worth TWP	DCD114	TDC517	DCG88	TDC469	DCD244	TDC531	TSS60			
D_8	E2O	DCG88	Hometown	TDC469	TSS60	DCG78							
D_8	E2	TDC414	Roberts Road	TDC531	DCG42	TSS60	DCG121						
D_8	E2	TDC469	Evergreen Park	TSS60	DCG78	DCG88							
D_8	E2	TDC517	Sayles	TDC531	DCD242	TDC550	DCD114						
D_8	E2	TDC531	Bridgeview	TDC517	TDC414	DCG78	DCG42						
D_9	K2	DCW41	Downer's Grove	TSS145	TDC557	TSS103							
D_9	K2	SS558	Westmont SS & TDC	TSS136	TSS145	TDC580							
D_9	J2	TDC555	Glen Ellyn	TSS145	TDC557	DCW30	TSS120						
D_9	J2	TDC557	Butterfield	TDC539	TDC555	TSS145	DCW41	TSS103					
D_9	J2	TSS145	York Center	TDC566	SS558	DCW41	DCW334	TDC552	TDC580	TDC557	TSS103	TSS120	
E_1	E1	DCD16	LaGrange Highlands	TSS134	DCD229								
E_1	E1	DCD229	Lyons TWP	DCD16	TDC593	TSS136	TSS51						
E_1	E1	DCW48	Hinsdale	SS553	TSS136	TDC566							
E_1	E1	DCW64	Bellwod	TDC580	TSS136								
E_1	E1	SS553	Hindsdale SS	TSS136	TDC566	DCW48							
E_1	E1	TDC593	Willow Springs	TSS136	DCD229	DCD242	DCD351	TSS51					
E_1	E1	TSS136	Burr Ridge	SS558	TDC593	TDC580	DCD229	DCW64	SS553	TSS134	DCD351	DCW48	
F_1	F2	SS460	Harvey SS	TDC465	TDS443								

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SA	Sq	Station	Name	Connected 12kV Stations (* "may include others")									
F_1	F2	TDC443	Harvey	TDC446	TSS76	TDC435	TDC465	SS460	TDC452				
F_1	F2	TDC446	Lansing	DCF149	TDC447	TDC452	TDC443						
F_1	F2	TDC447/477	Sand Ridge	TDC446	TDC458								
F_1	F2	TDC458	Green Lake	TDC447	TDC465								
F_1	E2	TDC465	South Holland	SS460	TSS76	TDC443	TDC458	TDC447					
F_1	F2	TSS76	Blue Island	TDC465	TDC461	TDC443	DCG128	TDC435	Beverly	Wildwood			
F_2	F1	DCG99	Palos Heights	TDC440	TSS60								
F_2	E2	TDC440	Palos TWP	DCG99	TDC419	TDC461	TDC416	TDC414	DCG121				
F_2	F1	TDC461	Crestwood	TSS76	TSS60	TDC419	TDC435	TDC440					
F_2	E2	TSS60	Alsip	DCG99	DCG42	TDC414	TDC469	DCG78	TDC461				
F_3	F1	DCG128	Markham	TDC435	TSS76								
F_3	F1	DCG19	Tinley Park	TDC419									
F_3	F1	TDC419	Tinley Park	TDC416	TDC440	TDC435	TDC451	TDC461					
F_3	F1	TDC435	Country Club Hills	TDC419	TDC443	TSS127	TDC451	TDC461	DCG128	TDC452	TSS76	SS459	
F_3	F1	TDC451	Mokena	TSS140	TDC419	DCJ38	TDC435						
F_4	F2	DCF12	Sauk Tail	DCF149	TDC452	TDC457							
F_4	F2	DCF122	Chicago Heights	TDC452	DCF96								
F_4	F2	DCF149	Lynwood	TDC446	DCF12								
F_4	F2	DCF73	Chicago Heights	DCF96	TDC452								
F_4	F2	DCF96	Chicago Heights	DCF122	TDC457	DCF73	TDC452						
F_4	F1	SS459	Vollmer Road	TSS127	TDC452	TDC435	TDC457						
F_4	F2	TDC452	Glenwood	DCF12	TDC446	TDC443	DCF96	TDC435	TDC457	DCF122	DCF73	DCF149	SS459
F_4	F2	TDC457	Park Forest	DCF12	DCF96								
F_4	F1	TSS127	Matteson	TDC457	TDC453	TDC435	TSS140	SS459					
G_1	G1	DCA31	Fox Lake	TSS42	DCE20	TDC228							
G_1	G1	DCE16	Mc Henry	TSS193	DCE20	TDC228							
G_1	G1	DCE17	South Wonder Lake	DCE82	DCE20	TSS193	DCE79	DCE21					
G_1	G1	DCE20	Spring Grove	DCA71	DCE16	TSS193	DCE17	DCE82	TDC230	DCA31			
G_1	G1	DCE79	SE Wonder Lake	DCE21	DCE17	TSS193							
G_1	G1	DCE82	Richmond	DCE20	DCE17								
G_1	G2	TDC228	Wilson	TSS42	DCA31	DCE16	DCA87	TSS154	DCE19	DCE11	DCE22		
G_1	G2	TSS193	Mc Henry	DCE16	DCE79	DCE17	DCE20	TSS75					
G_2	G2	DCE19	Island Lake	DCE11	DCE46	TDC228							

SA	Sq	Station	Name	Connected 12kV Stations			(* "may include others")				
G_2	G2	DCE24	Cary	TSS138	TDC240	TSS75					
G_2	G2	DCE46	Burtons Bridge	DCE19	TSS138						
G_2	H1	DCE77	SO Crystal Lake	TSS75	TDC250	DCE26	DCE28				
G_2	H1	TDC240	Cary	DCE24	TSS75	TDC250					
G_2	G2	TSS138	Silver Lake	DCE24	TSS75	DCE46					
G_2	G2	TSS75	Crystal Lake	DCE71	DCE24	DCE77	DCE26	TDC240	TSS138	TSS193	TSS151
H_1	G2	DCE11	Wauconda	DCE22	TDC248	DCE19	TDC228	DCE18			
H_1	H1	DCE18	Honey Lake	DCE11	TDC233	DCE22					
H_1	G2	DCE22	Wauconda	TDC228	DCE18	DCE11	TDC248				
H_1	H1	SS284	Barrington SS	TDC233	TDC248						
H_1	H1	TDC233	Barrington	DCE18	TSS102	TDC248	TDC260	SS284			
H_1	B1	TDC248	Lake Zurich	TSS109	TDC233	SS284	TSS102	DCE11	TSS166		
H_2	N2	DCE10	South Huntley	DCE35							
H_2	N2	DCE26	Lake in the Hills	DCE28	DCE77	DCE35	TDC572	DCE71	TSS75		
H_2	H1	DCE28	Algonquin	DCE77	TDC572	DCE59	DCE26	TDC250			
H_2	N2	DCE35	Huntley	TDC572	DCE10	DCE26					
H_2	H1	DCE59	Haeger's Corner	TDC260	DCE28	TDC250					
H_2	H1	DCW218	Carpentersville	TDC260	TDC572						
H_2	H2	TDC235	Poplar Creek	TDC214	TDC260						
H_2	H1	TDC250	Barrington Hills	TDC260	DCE59	DCE28	DCE77	TDC240			
H_2	H1	TDC260	Dundee	TDC563	DCE59	DCW218	TDC572	TDC235	TDC250	TDC233	TDC214
H_3	H2	DCW26	Elgin TWP	TDC570	TDC572						
H_3	H2	DCW28	Sunset Park	TDC570	TDC577						
H_3	H2	TDC563	Hanover Township	TDC570	TDC260	TDC574	TDC214	TSS79			
H_3	H2	TDC570	Elgin SS	DCW25	TDC563	DCW26	TDC572	DCW28	TDC577		
H_3	H2	TDC572	Gilberts	DCW25	DCW26	DCW218	DCE28	DCE26	TDC260	TDC570	
J_1	J2	DCW30	Wheaton	TDC595	TDC539	DCW31	DCW340	DCW336	TDC555		
J_1	J1	DCW302	Warrenville	TDC539	TDC581						
J_1	J1	DCW31	Milton TWP	TDC595	DCW336						
J_1	J2	DCW336	Milton TWP	DCW31	TDC539	DCW340	DCW30	TDC595			
J_1	J2	DCW340	Wiesbrook	DCW336	TDC539						
J_1	K2	DCW44	Yender Road	TSS103							
J_1	K2	DCW46	Naperville	TDC559	TSS103						
J_1	J1	TDC539	Warrenville	TSS103	DCW30	TDC557	DCW340	DCW336	DCW302	DCW29	TDC595
J_1	K2	TSS103	Lisle	DCW41	TDC557	DCW44	TDC580	TDC559	DCW46	TDC539	TSS145
J_2	J1	DCE08	Nerge	TDC574	TDC220	TDC253	DCW236				
J_2	J1	DCW233	Bartlett	TSS79	TDC574						
J_2	J2	DCW236	Roselle	TDC574	TDC562	TDC565	DCE08	TDC220			

SA	Sq	Station	Name	Connected 12kV Stations (* "may include others")										
J_2	J1	DCW33	Wayne	TSS131	TDC574									
J_2	J1	TDC574	Bartlett	DCE08	DCW233	DCW236	DCW33	TSS79	TDC562	TDC220	TDC595	TDC214	TDC563	TDC562
J_2	H2	TSS79	Spaulding	DCW233	DCW10	TDC563	DCW202	TDC574						
J_3	J1	DCW10	Fox River Heights	TDC577	TSS79									
J_3	J1	DCW102	Fabyan	TDC569	DCW39	DCW19								
J_3	J1	DCW115	Glenwood Park	DCW50	DCW29	TSS131								
J_3	J1	DCW29	Winfield TWP	DCW115	DCW336	TDC539	TDC581							
J_3	J1	DCW335	West Chicago	TSS131	DCW336	DCW29	TDC539							
J_3	J1	TDC577	South Elgin	DCW10	TDC570	DCW211	DCW28	DCW39	DCW202					
J_3	J1	DCW202	South Elgin	TSS79	TDC577									
J_3	J1	TSS131	West Chicago 12kV	DCW335	DCW33	TDC595	DCW115							
K_1	K2	DCW38	Downers Grove TWP	DCJ92	TDC561	TDC580	TDC411							
K_1	K2	TDC559	Woodridge	DCW46	TDC580	TDC561	TSS103							
K_1	K2	TDC561	Bolingbrook	TDC559	DCW38	TDC580	TDC411	DCJ92						
K_1	K2	TDC580	Downers Grove	TSS136	TDC559	TSS145	SS558	DCW38	TDC561	DCW64	TSS103			
---	N4	DCW113	Waterman	See TSS 106										
K_2	K1	DCW148	Liberty Street	TSS56	TDC581	TDC592	SS513							
K_2	K1	DCW152	Kensington	SS513	DCW18	TDC569	TSS56							
K_2	J1	DCW16	Indian Trail	TSS56	TDC569	DCW50	DCW51							
K_2	J1	DCW51	Randall Road	DCW50	DCW16	TSS56								
K_2	K1	SS513	Aurora SS	TSS106	DCW152	DCW18	DCW148	TSS106	TSS56					
K_2	K1	TDC581	Frontenac	DCW148	TDC454	TDC592	TDC561	DCW302	DCW29					
K_2	K1	TDC592	Oswego	TDC581	DCW113	DCW148	TSS106							
K_2	K1	TSS56	North Aurora	SS513	DCW148	DCW16	TDC581							
L_1	L1	DCJ16	Joliet	TDC456	TDC474									
L_1	L2	DCJ18	Lockport	TDC456	DCJ19	TDC487								
L_1	L2	DCJ19	Bruce Road	SS450	TDC456	DCJ62	DCJ49	DCJ18						
L_1	L2	DCJ38	Messenger Woods	TDC451	TDC 416									
L_1	L2	DCJ49	Cougar	TDC416	DCJ19	DCJ62								
L_1	L2	DCJ60	New Lenox	TSS140	TDC474									
L_1	L2	DCJ62	Homer TWP	DCJ49	DCJ19	TDC474	DCJ60							
L_1	L2	SS450	Joliet	TDC456	TDC474	DCJ19								

SA	Sq	Station	Name	Connected 12kV Stations			(* "may include others")			
L_1	L2	TDC456	Joilet Central	TDC436	DCJ18	TDC474	DCJ19	SS450	DCJ16	TDC439
L_1	L2	TDC474	Briggs	DCJ65	TDC456	DCJ58	SS450	DCJ60	DCJ62	
L_1	F1	TSS140	Frankfort	TDC451	TDC453	TSS127	DCJ60			
L_2	L1	DCJ17	Troy	TDC439	TDC431					
L_2	L1	DCJ31	Plainfield	TDC436	TDC454					
L_2	L1	DCJ59	Plainfield	TDC454						
L_2	L1	TDC431	Shorewood	DCJ17	TDC436	TDC454				
L_2	L1	TDC436	Hillcrest	TDC456	DCJ31	TDC411	TDC439	DCJ31	TDC431	
L_2	L1	TDC439	Rockdale	TDC456	DCJ17	TDC436				
L_2	L1	TDC454	Plainfield	DCJ59	TDC581	TDC431	DCJ24	DCJ31		
L_3	E1	DCJ87	Lemont	TDC487	TDC416	DCJ92				
L_3	L2	DCJ92	Main Station	TDC561	DCW38	TDC487	DCJ87			
L_3	L2	TDC411	Romeoville	TDC487	TDC436	DCW38	TDC561			
L_3	L2	TDC416	Bell Road	TDC440	TDC419	DCJ49	TDC487	DCJ38		
L_3	L2	TDC487	Archer	DCJ92	DCJ18	TDC416	TDC411	DCJ18	DCJ49	
MOC	M2O	DCJ32	Kahler Road	DCJ69	TSS149					
MOC	M1O	DCJ66	Goose Lake	DCJ68						
MOC	L1O	DCJ68		DCJ69	DCJ66					
MOC	L1O	DCJ69		TSS149	DCJ68	DCJ32				
MOC	M2O	TSS149	Wilmington	DCJ69	DCJ32					
MOE	M3O	DCF16	Beecher	DCF36	DCF17	DCK44				
MOE	M3O	DCF17	Peotone	DCF16	DCK20					
MOE	M3O	DCF36	Goodenow		DCF45					
MOE	F2O	DCF45	Crete	TDC453	DCF12	TDC457				
MOE	M3O	DCJ58	Matthatton	TDC474	TDC453					
MOE	M4O	DCK15	Warner Bridge	DCK32	TSS157	DCK34	TSS70			
MOE	M4O	DCK18	Momence	DCK44	DCK32	DCK45				
MOE	M4O	DCK19	Cemetery Road	DCK20	DCK44	TSS70				
MOE	M4O	DCK20	Manteno	DCF17	DCK19	DCK15	TSS70	TDC453		
MOE	M4O	DCK32	Aroma Park	DCK18	DCK39	DCK45	TSS157			
MOE	M4O	DCK33	Kankakee	DCK42	TSS70	TSS157				
MOE	M4O	DCK34	Lehigh	TSS157	DCK15	DCS47				
MOE	M4O	DCK39	Exline Road	TSS70	DCK32	DCK18				
MOE	M4O	DCK42	East Kankakee	DCK32	DCK33	TSS157				
MOE	M4O	DCK44	Grant Park	DCK19	DCK18	DCF16				
MOE	M4O	DCK45	St.Anne	DCK18	DCK32					
MOE	M3O	TDC453	Woodhill	TSS140	TSS127	DCJ58	DCK20	TDC457	DCF45	
MOE	M4O	TSS157	Kankakee	TSS70	DCK15	DCK32	DCK42	DCK34	DCK33	

SA	Sq	Station	Name	Connected 12kV Stations				(* "may include others")		
MOE	M4O	TSS70	Bradley	DCK33	TSS157	DCK19	DCK39	DCK20	DCK15	
MOW	M1O	DCJ13	Wauponsee	SS422						
MOW	M1	DCJ21	---	DCJ33	DCJ28					
MOW	M1O	DCJ24	Lisbon	TDC454	SS422	DCJ65	DCW118			
MOW	M1	DCJ27	---	DCJ28						
MOW	M1O	DCJ28	---	DCJ21	DCJ27					
MOW	M1	DCJ33	Washington Street	DCJ21	SS422					
MOW	P2O	DCJ65	Seneca	DCJ24	DCJ76					
MOW	P2O	DCJ76	Dupont Road	DCJ65	DCS36					
MOW	P3O	DCS26	Blackstone	SS462						
MOW	P2O	DCS36	Verona	DCJ76	DCS67					
MOW	M2O	DCS47	South Wilmington	DCS63	DCS43	SS462	DCK34			
MOW	M2O	DCS63	Gardner	DCS47	SS462					
MOW	M2O	DCS67	Mazon	SS462	DCS35					
MOW	M1O	SS422	Morris SS	DCJ24	DCJ65	DCJ33				
MOW	M2O	SS462	Dwight	DCS26	DCS43	DCS47	DCS63	DCS65		
N_1	N2	DCB10	Harvard	DCE21	DCB31	DCB51				
N_1	N2	DCB12	Capron	NO TIES						
N_1	N2	DCB31	Chemung	DCB10						
N_1	N2	DCB32	Garden Prairie	NO TIES						
N_1	N2	DCB51	Marengo	DCB10	TSS123	DCB57				
N_1	N2	DCB57	Union	DCB51						
N_1	N2	DCE21	Hartland	TSS151	DCE17	DCE79	DCB10			
N_1	H1	DCE71	Dorr TWP	DCE21	DCE26	TSS151				
N_1	N2	SS318	Harvard	no ties						
N_1	N2	TSS123	Marengo	DCB51						
N_1	N2	TSS151	Woodstock	DCE21	DCE71	TSS75				
N_2	N4	DCB90	Maple Park	TSS83	DCW19	DCW20				
N_2	N4	DCW17	West Sugar Grove	TDC569						
N_2	N4	DCW18	Sugar Grove	DCW50	TDC569	SS513	DCW152	TSS56	TSS106	
N_2	N4	DCW19	Blackberry TWP	DCW20	DCW39	TDC569	DCB90	DCW102		
N_2	N4	DCW20	Lily Lake	DCW211	DCW39	DCW19				
N_2	N4	DCW211	Plato Ctr	TDC577	DCW20	DCW39	DCW25			
N_2	H2	DCW25	Pingree Grove	TDC570	DCW211	TDC572				
N_2	N4	DCW39	Wasco	DCW211	DCW20	DCW102	DCW19	TDC577		
N_2	N4	DCW50	Deerpath Road	DCW18	DCW51	TDC569	DCW16	DCW115		

SA	Sq	Station	Name	Connected 12kV Stations (* "may include others")											
N_2	N4	TDC569	Sugar Grove	DCW50	DCW18	DCW16	DCW17	DCW19	DCW102	TSS56	DCW152	DCW19			
N_3	N2	DCB15	Kingston	DCB17	DCB28										
N_3	N2	DCB16	Hampshire	DCB17											
N_3	N2	DCB17	Genoa	DCB16	DCB15										
N_3	N1	DCB28	Kirkland	DCB15											
N_3	N3	DCB86	Clare	TDC375											
N_3	N4	DCB89	Afton	DCB95	TDC375										
N_3	N4	DCB95	South DeKalb	TSS83	TDC375	DCB89									
N_3	N4	SS316	Sycamore SS	TSS83	TDC375										
N_3	N3	TDC375	West Dekalb	DCB86	DCB89	TSS83	SS316								
N_3	N4	TSS83	Glidden	DCB90	SS316	TDC375									
N_4	N4	DCH47	Hinckley	NONE											
N_4	N3	DCH52	Leland	NONE											
N_4	N4	DCH53	Somonauk	SS314											
N_4	N4	DCH54	Waterman	DCH56											
N_4	N4	DCH60	Sandwich	DCH65	SS314										
N_4	N4	DCH65	Plano	DCH60											
N_4	N4	DCW118	Kendall	TSS106	DCW12	DCJ24									
N_4	N4	DCW119	Bristol TWP	DCW12	TSS106										
N_4	N4	DCW12	Yorkville	DCW119	TSS106	DCW118									
N_4	N4	SS314	Sandwich SS	DCH53	DCH60										
N_4	K1	TSS106	Montgomery	SS513	TDC592	DCW18	DCW118	DCW12	DCW119						
N_5	N2	DCB11	Poplar Grove	NO TIES											
N_5	N1	DCB20	Belvidere	TSS122											
N_5	N1	TDC388	Harlem	TSS164	TSS163										
N_5	N1	TDC389	Bell School	TSS164	TSS160	TSS122									
N_5	N1	TSS122	Belvidere	TDC389	DCB20										
N_5	N1	TSS160	Alpine	TDC380	TDC384	TSS165	TSS164	TDC389							
N_5	N1	TSS164	Sand Park	TSS160	TSS163	TSS165	TDC388	TDC389							
N_6	N1	TDC380	Charles	TSS165	TSS160	TDC385	TDC384								
N_6	N1	TDC385	15th Street	TDC380	TSS194	TSS165									
N_6	O2	TSS162	Pierpont	TDC387	TDC386	TSS165	TSS163								
N_6	N1	TSS163	Roscoe Bert	TSS165	TSS162	TDC388	TDC386	TSS164							
N_6	N1	TSS165	Fordham	TSS162	TSS163	TSS164	TSS160	TSS194	TDC380	TDC385					
N_6	N1	TSS194	Sabrooke	TDC385	TDC387	TSS165									

SA	Sq	Station	Name	Connected 12kV Stations (* "may include others")											
P1	P3O	DCS11	Rowe	SS471											
P1	P2O	DCS14	Kernan	DCS48											
P1	P1O	DCS15	Toluca	DCS39	DCS20										
P1	P1O	DCS16	Wenona	DCS20											
P1	P1O	DCS20	Rutland	DCS42	DCS39	DCS15									
P1	P1O	DCS21	Lostant	DCS29											
P1	P2O	DCS25	Grand Rapids Twp.	DCS29											
P1	P2O	DCS27	Lowell	NO 3PH TIES											
P1	P2O	DCS29	Grand Ridge	DCS21	DCS25	DCS37									
P1	P2O	DCS35	Manville	NO 3PH TIES											
P1	P20	DCS37	Bruce TWP	DCS29	DCS48										
P1	P1O	DCS39	Minonk	DCS20	DCS15										
P1	P3O	DCS40	Lodemia	DCS41	DCS43										
P1	P3O	DCS41	Eppards Pt. TWP	DCS40											
P1	P3O	DCS42	Cornell	DCS20											
P1	P3O	DCS43	Odell	SS462	DCS47	SS471									
P1	P2O	DCS44	Streator	DCS48											
P1	P2O	DCS48	Otter Creek	DCS44	DCS37										
P1	P3O	DCS66	Pontiac	SS471											
P1	P3O	SS471	Pontiac	DCS66	DCS43	DCS11									
Q_1	N1	DCB26	Davis Junction	DCB27											
Q_1	Q2	DCB27	Stillman Valley	DCB26											
Q_1	Q2	DCB29	Byron	NO TIES											
Q_1	Q2	DCB30	Mt. Morris	DCB53											
Q_1	Q2	DCB52	Leaf River	NO TIES											
Q_1	Q2	DCB53	Oregon	DCB54	DCB30										
Q_1	Q2	DCB54	Oregon	DCB53											
Q_1	Q2	DCB55	Rock City	DCB47	TDC386										
Q_1	N1	TDC384	Harrison	TDC387	TSS160	TDC380									
Q_1	Q2	TDC386	Pecatonica	DCB55	TSS163	TSS162	DCB39								
Q_1	N1	TDC387	Blackhawk	TDC384	TSS162	TSS194									
Q_2	Q4	DCB64	Franklin Grove	DCH49											
Q_2	N3	DCH39	Mendota	SS311											
Q_2	Q4	DCH43	Amboy	DCH67											
Q_2	Q4	DCH44	Ohio	DCH40											
Q_2	Q4	DCH49	Ashton	DCB64											
Q_2	N3	DCH50	Earlville	NONE											
Q_2	N3	DCH56	Shabbona	DCH57	DCH54										
Q_2	N3	DCH57	Lee	DCH56											

SA	Sq	Station	Name	Connected 12kV Stations (* "may include others")			
Q_2	N3	DCH59	Paw Paw	DCH70			
Q_2	Q4	DCH67	Amboy	DCH43	DCH70		
Q_2	Q4	DCH70	Sublette	DCH67	DCH59	SS311	
Q_2	Q4	DCH78	Dixon	TDC317			
Q_2	N3	SS311	Mendota SS	DCH39	DCH70		
Q_2	N3	SS312	Steward	NO TIE			
Q_2	Q4	TDC317	Dixon	DCH10	DCH78	TSS133	
Q_3	Q1	DCB36	Polo	NO TIES			
Q_3	Q1	DCB37	Forreston	DCB39			
Q_3	Q1	DCB39	Baileyville	TSS121	DCB37		
Q_3	Q1	DCB47	Cedarville	DCB55	DCB48	TSS121	
Q_3	Q1	TDC370	Eleroy	TSS121			
Q_3	Q1	TSS121	Freeport	TDC370	DCB39	DCB47	
Q_4	Q3	DCH10	Prairieville	DCH62	TDC372	TDC317	
Q_4	Q3	DCH25	Sterling	TDC372	DCH27		
Q_4	Q3	DCH27	Galt	DCH25			
Q_4	Q3	DCH40	Walnut	DCH44	TSS133		
Q_4	Q3	DCH41	Rock Falls	TSS133			
Q_4	Q3	DCH62	Stirling	DCH10	TDC372		
Q_4	Q3	TDC372	IDC Sterling	DCH10	DCH 62	DCH25	
Q_4	Q3	TSS133	Rock Falls	DCH41	DCH40	TDC317	
Q1O	Q1O	DCB35	Coleta	DCB46			
Q1O	Q1O	DCB42	Pearl City	DCB45			
Q1O	Q1O	DCB43	Stockton	DCB45			
Q1O	Q1O	DCB44	Warren	DCB45			
Q1O	Q1O	DCB45	Lena	DCB48	DCB42	DCB43	DCB44
Q1O	Q1O	DCB46	Milledgeville	DCB35			
Q1O	Q1O	DCB48	Rink Road	DCB45	DCB47		
Q1O	Q1O	DCB50	Cherry Grove	DCB63			
Q1O	Q1O	DCB63	Lanark	DCB50			
Q3O	Q3O	DCH23	Fulton	TSS132	DCH26		
Q3O	Q3O	DCH26	Morrison	TSS132	DCH23		
Q3O	Q3O	DCH28	Lyndon	TSS132	DCH91		
Q3O	Q3O	DCH36	York Town	DCH91	DCH38		
Q3O	Q3O	DCH38	Hooppole	DCH36			
Q3O	Q3O	DCH91	Prophetstown	DCH28	DCH36	DCH41	

SA	Sq	Station	Name	Connected 12kV Stations (* "may include others")											
Q3O	Q3O	TSS132	Garden Plain	DCH28	DCH26	DCH23									
X_1		TSS114	Northwest Lines	TSS35	TSS54	TSS82	TSS84	TSS110	TSS39	TSS32	TSS38	*			
X_1		TSS35	Lakeview	TSS54	TSS82	*									
X_1		TSS54	Clybourne	TSS82	*										
X_2		TSS39	Portage	TSS110	TSS71	TSS31	TSS68	TSS114	TSS37	*					
X_2		TSS110	Devon	TSS84	TSS114	*									
X_2		TSS84	Rosehill	TSS114	*										
X_2		TSS71	Higgins	TSS114	*										
X_3		TSS32	Hanson Park	TSS37	TSS31	TSS30	TSS38	TDC648	TSS114	*					
X_3		TSS37	Natoma	TSS31	TSS30	TSS38	TDC648	TSS39	*						
X_3		TSS31	Galewood	TSS30	TSS38	TDC648	TSS39	*							
X_3		TSS30	Columbus Park	TSS38	TDC648	STA13	STA25	*							
X_3		TSS38	Humboldt	TDC648	STA13	STA25	TSS114	TSS82	STA11	TDC714	TSS44	TSS45	*		
X_3		TDC648	Norridge	TSS71	*										
X_4		TSS33	Hayford	STA13	STA25	TSS63	TSS104	TDC814	TDC469	*					
X_4		STA13	Crawford	STA25	TSS63	TSS104	TDC814	TSS30	TDC714	TSS38	STA11	*			
X_4		STA25	Crawford Lines	TSS63	TSS104	TDC814	TSS30	TDC714	TSS38	STA11	TDC840	*			
X_4		TSS63	Sawyer	TSS104	TDC814	TSS137	*								
X_4		TSS104	Ford City	TDC814	*										
X_4		TDC814	Damen	TSS137	TSS118	TDC469	*								
X_5		TSS87	Dearborn	TSS49	TDC784	TDC745	TSS68	TSS44	TSS45	STA11	TSS65	TDC785	TSS38	TDC714	
X_5		TSS49	Plymouth Court	TDC784	TDC745	TSS68	TSS44	TSS45	STA11	TSS65	TDC785	TSS38	TDC714		
X_5		TDC784	Sears Tower	TDC745	TSS68	TSS44	TSS45	STA11	*						
X_5		TDC745	IC Air Rights	TSS68	TSS44	TSS45	STA11	TSS65	TDC785	TSS38	TDC714	*			
X_5		TSS68	LaSalle	TSS44	TSS45	STA11	TSS65	TDC785	TSS38	TDC714	*				
X_5		TSS44	Vernon Park 44	TSS44	TSS45	STA11	TSS65	TDC785	TSS38	TDC714	*			*	
X_6		TSS65	Ohio	TSS34	TSS82	TDC785	TSS45	TDC745	TSS87	TDC784	TSS49	TSS63	TSS44		

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SA	Sq	Station	Name	Connected 12kV Stations (* "may include others")											
X_6		TSS34	Kingsbury	TSS82	TDC785	TDC745	TSS87	TDC784	TSS49	TSS63	TSS44	TSS68	*		
X_6		TSS82	Crosby	TSS38	TSS54	TSS45	TSS87	TDC784	TSS49	TSS63	TSS44	TSS68	*		
X_6		TDC785	Ontario	TSS45	STA11	TDC745	TSS87	TDC784	TSS49	TSS63	TSS44	TSS68	*	*	
X_7		TSS45	Jefferson	TDC840	TDC714	STA11	TSS44	TSS38	TDC785	TSS65	TDC745	TSS68	STA25	*	
X_7		TDC840	Quarry	TDC714	STA11	TSS44	TSS38	TSS82	TDC785	TDC745	TSS49	TSS68	STA25		
X_7		TDC714	Medical Center	STA11	TSS44	TSS38	TDC785	TSS65	TDC745	TSS49	TSS68	STA25	*		
X_7		STA11	Fisk	TSS44	TSS38	TDC785	TSS65	TDC745	TSS87	TSS49	TSS68	STA25	*		
X_8		TSS43	Wildwood	TSS41	TSS55	TSS150	TSS89	*							
X_8		TSS41	Roseland	TSS55	TSS150	TSS89	TSS118	*							
X_8		TSS55	Hegewisch	TSS150	*										
X_8		TSS150	Calumet	TSS118	TSS137	*									
X_9		TSS89	Beverly	TSS118	TSS137	TSS174	TDC840	STA11	TSS150	TSS41	TSS43	*			
X_9		TSS118	Wallace	TSS137	TSS174	TDC840	STA11	TSS150	*						
X_9		TSS137	Washington Park	TSS174	TDC840	STA11	TSS63	TDC814	TSS150	*					
X_9		TSS174	University	TDC840	STA11	TSS150	*								